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Remedial Action Status Report Revision 2

Olalla Landfill
Southeast Burley-Olalla Road
Kitsap County, Washington

Prepared For:

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March 29, 2023

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ACRONYMS AND ABBREVIATIONS

Abbreviation/ Acronym	Definition
bgs	Below ground surface
CAP	Cleanup Action Plan
cm/sec	Centimeters per second
CMP	Compliance Monitoring Plan
COC	Constituent of concern
CPOC	Conditional point of compliance
CUL	Cleanup level
DO	Dissolved oxygen
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EPI	Environmental Partners, Inc.
KCBH	Kitsap County Board of Health
KCPW	Kitsap County Department of Public Works
KPHD	Kitsap Public Health District
Landfill	Olalla Landfill
LCL	Lower confidence limit
LEL	Lower explosive limit
MFS	Minimum Functional Standards for Solid Waste Handling (WAC 173-304-407)
µg/L	Micrograms per liter
mg/kg-day	Milligrams per kilogram per day
MNA	Monitored natural attenuation
MSW	Municipal solid waste
MTCA	Model Toxics Control Act
ORP	Oxidation-reduction potential
Permit	Solid Waste Landfill Post Closure Permit
Qob	Olympia Beds
Qva	Vashon Advance Outwash Deposits
Qvi	Vashon Ice-Contact Deposits
Qvr	Vashon Recessional Outwash Deposits
Qvt	Vashon Till
RASR	Remedial Action Status Report
RI	Remedial Investigation
RI/FS	Remedial Investigation / Feasibility Study
SWHP	Solid Waste Handling Permit
TRC	TRC Environmental Corporation
UCL	Upper confidence limit
VOCs	Volatile organic compounds
WAC	Washington Administrative Code

1.0 INTRODUCTION

This *Remedial Action Status Report (*RASR) presents the results of technical evaluations that have been performed since 2017 at the closed Olalla Landfill (the Landfill) in Kitsap County, Washington. The intent of this RASR is to provide the Washington State Department of Ecology (Ecology) with a comprehensive remedial action update for the Landfill consistent with criteria in Washington Administrative Code (WAC) 173-340-420(4). The RASR also contains evaluations of the protectiveness and effectiveness of cleanup actions taken at the Landfill.

1.1 Site Location

The Landfill is located approximately 0.75 mile east of Highway 16 on Southeast Burley-Olalla Road in Kitsap County Washington as shown on Figure 1. The Landfill property is bounded to the north by Southeast Burley-Olalla Road, to the east by Bandix Road Southeast, to the south by a Kitsap County-owned parcel that is used as an off-leash dog park, and to the west by three privately-owned parcels.

1.2 Purpose of Report

This *RASR* was prepared by TRC Environmental Corporation (TRC) on behalf of Kitsap County Department of Public Works (KCPW) Solid Waste Division as noted in Section 7.0 of the approved *Olalla Landfill Cleanup Action Plan* (Parametrix 2014).

The criteria to be evaluated as part of the 5-year review process are described in Ecology's Model Toxics Control Act (MTCA), specifically in Washington Administrative Code (WAC) 173-340-420(4). The six criteria that are evaluated to determine if cleanup actions are protective of human health and the environment must include the following.

a) *The effectiveness of ongoing or completed cleanup action, including the effectiveness of engineered controls and institutional controls in limiting exposure to hazardous substances remaining at the site.*

b) *New scientific information for individual hazardous substances or mixtures present at the site.*

c) *New applicable state and federal laws for hazardous substances present at the site.*

d) *Current and projected site and resource uses.*

e) *The availability and practicability of more permanent remedies.*

f) *The availability of improved analytical techniques to evaluate compliance with cleanup levels.*

1.3 Report Organization

This RASR for the Landfill is organized into the following sections, which includes evaluations for each of the six evaluation criteria presented in Section 1.2.

- Section 1.0 – Introduction
- Section 2.0 – Summary of Site Conditions
- Section 3.0 – Remedial Measures
- Section 4.0 – Effectiveness of Cleanup Actions
- Section 5.0 – Data Evaluations
- Section 6.0 – New Information and Laws
- Section 7.0 – Current and Projected Site and Resource Use
- Section 8.0 – Availability and Practicability of Alternative Remedies
- Section 9.0 – Improved Analytical Methods
- Section 10.0 – Proposed Actions for 2021 to 2025
- Section 11.0 – References

2.0 SUMMARY OF SITE CONDITIONS

2.1 Site Description and History

The current tax identification number for the Landfill property is 012201-1-029-2003. The original Landfill parcel consisted of approximately 75 acres, which contained a former gravel pit. In 1996 the original parcel was subdivided into two parcels: a 45-acre parcel to the north, which contains the Landfill, and a 30-acre parcel to the south. The north parcel contains the closed Landfill and a transfer station facility, referred to as a Recycling and Garbage Facility, which was established at the time the Landfill stopped accepting waste. The section of the north parcel containing the Recycling and Garbage Facility was never used as a landfill. The south parcel also was never used as a landfill, is not part of the Landfill Site, and currently serves as an off-leash dog park.

The Landfill consists of two areas designated the Phase I Closure Area (Phase I Area) and the Phase II Area as shown on Figure 2. The 6.5-acre Phase I Area consists of an engineered low-permeability clay-amended vegetated protective soil cap. The 4.5-acre Phase II Area is covered with vegetated soil. Both areas are surrounded by a gravel perimeter access road that encompasses approximately 12 acres. Neither the Phase I nor Phase II Areas contain an engineered bottom liner. The closed Landfill is served by a groundwater monitoring well network, a surface water conveyance system and stormwater detention pond, a passive landfill gas collection system, public access controls, and a surrounding vegetation buffer.

Available records indicate that the Landfill began receiving waste in the late 1950s or early 1960s; however, the specific year that waste disposal began at the Landfill is not documented. During that time, the Landfill accepted solid waste from residential and light commercial self-haulers. The types of waste disposed at the Landfill included demolition and construction materials, mixed municipal solid waste, and a small volume of septic sludge.

Initial Landfill operations reportedly consisted of controlled burning of the refuse and covering the burned waste with soil on monthly intervals. The practice of burning waste material was terminated at the Landfill in the early 1970s. In late 1971 KCPW took over operation of the Landfill and operated in the facility in accordance with the solid waste regulations and practices at the time, which included compaction of the waste and daily soil cover of the compacted waste.

The earliest known operating permit for the Landfill was issued in 1969 by the Bremerton Kitsap County Health District, now known as the Kitsap Public Health District (KPHD). The 1969 permit was issued to a private operator and allowed the Landfill to accept waste from residential and light commercial self-haulers. Language in the 1969 permit letter indicates that the Landfill might have been permitted several years prior to 1969.

In 1978, KPHD approved a request to dispose of 300,000 gallons of septic tank waste at the Landfill. However, the actual volume of septic waste that the Landfill received is unknown. Before this time, waste streams at the Landfill were limited to domestic wastes with occasional loads of demolition wastes (Parametrix 1988). Estimates performed in 1982 indicate that the Landfill received approximately 2,000 cubic yards of mixed municipal solid waste per month. A transfer station began operations in the northern part of the property in the spring of 1985, and the Landfill stopped accepting waste after that time. The transfer station is now operating as the Recycling and Garbage Facility.

Four groundwater monitoring wells, designated MW-1 through MW-4, were installed at the Landfill after the Landfill stopped accepting waste in 1985. Wells MW-5, MW-5A, MW-6, and MW-7 were installed between 1988 and 1993 to expand the long-term groundwater monitoring well network. Wells MW-8 and MW-10 were installed in 2010 as part of the Remedial Investigation (RI) conducted between 2010 and 2014. Well identification number MW-9 was skipped because historically, MW-9 was used as the fictitious well identification number for field duplicate samples. The monitoring well locations are shown on Figure 2.

In 1989, the Landfill was officially closed pursuant to WAC 173-304, and the Landfill was divided into the Phase I and Phase II Areas. Closure activities included grading the surface of both areas to facilitate drainage and construction of an engineered 2-foot-thick bentonite clay amended soil cap over the Phase I Area. A passive landfill gas collection system consisting of three landfill gas flares connected by underground perforated piping installed under the low-permeability cap. Following cap installation, both the Phase I and Phase II Areas of the Landfill were vegetated with grass that is maintained and inspected by KCPW. Long-term post-closure monitoring activities, including quarterly groundwater monitoring, quarterly landfill gas monitoring, and annual surface water monitoring have been ongoing since Landfill closure.

2.2 Regulatory Background

The Landfill was closed in 1989 in accordance with the *Olalla Final Closure Plan* (Parametrix 1988). Post-closure activities have consisted primarily of quarterly monitoring and maintenance per WAC 173-304-407 (Minimum Functional Standards for Solid Waste Handling [MFS]), "General Closure and Post Closure Requirements" Kitsap County Board of Health Ordinance 2010-01 "Solid Waste Regulations" and Solid Waste Handling Permits (SWHP) issued annually by the KPHD.

KCPW is performing an independent cleanup action under the MTCA, with technical consultation from Ecology. A Remedial Investigation/Feasibility Study (RI/FS) was performed at the Landfill starting in May 2010 and ending May 2014 when the RI/FS was submitted to Ecology and KPHD (Parametrix 2014a). In a September 5, 2014, opinion letter, Ecology approved cleanup levels, a conditional point of compliance, and the preferred cleanup alternative of monitored natural attenuation (MNA). Ecology stated the MNA alternative should be evaluated for effectiveness at 5-year intervals and additional cleanup alternatives should be re-considered within 10 years based on performance data. Upon approval of the RI/FS, KCPW prepared a *Cleanup Action Plan* (CAP) to summarize the RI/FS activities and present the preferred cleanup action, which was selected based on the results of the RI/FS. Ecology and KPHD approved the CAP in December 2014 (Parametrix 2014b).

In 2016 KPHD issued a Solid Waste Landfill Post Closure Permit for 2016–2020 (the Permit). The approved cleanup action (MNA and land use controls) is based on a continuation of ongoing groundwater, surface water, and landfill gas monitoring in accordance with the SWHP. Quarterly monitoring results will be used to evaluate the effectiveness of the cleanup action and to verify that natural attenuation continues to occur at the Landfill. The overall effectiveness of the cleanup action will be evaluated at 5-year intervals as part of the periodic review process as documented in this RASP.

2.3 Regional and Local Hydrogeology

Local and regional hydrogeologic data were reviewed available regional geologic information to identify the geologic units that were encountered at the Landfill and surrounding area during drilling. The consulting team reviewed historical geologic logs for Landfill monitoring wells and for water supply and other wells installed in the area surrounding the Landfill. More recent geologic logs were also generated during drilling for wells MW-8 and MW-10, which were installed in the area west and northwest of the Landfill in 2010. This information was used to prepare summary descriptions of the regional and local hydrogeology for the Landfill as presented in the following sections.

2.3.1 Regional Hydrogeology

The hydrogeology encountered beneath the Landfill is composed of granular deposits emplaced during the Vashon glaciation as described in the RI/FS (Parametrix 2014a). Geologic formations underlying the Landfill contain three distinct occurrences of groundwater beneath the Landfill, from shallowest to deepest are described below:

- The shallow perched groundwater zone, which is perched on top of the ice-contact deposits (Qvi) and is found only at MW-5, MW-5A, and the South Kitsap County Transfer Station Well.

- The uppermost unconfined aquifer, which occurs in the advance outwash deposits (Qva).

- The deeper confined aquifer, which occurs in the Olympia Beds (Qob).

These geologic formations are described in the Geologic Map of the Olalla 7.5′ Quadrangle King, Kitsap, and Pierce Counties, Washington (Booth and Troost 2005) and are summarized below starting with the uppermost formation present at the Landfill:

- **Recessional Outwash Deposits (Qvr)** – Stratified sand and gravel, moderately well sorted to well sorted, less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow. At the Landfill the Qvr formation occurs as light brown poorly graded sand that is present in areas north, south, and east (upgradient) of the Landfill but is not present beneath the Landfill itself and is also not present in geologic logs at downgradient well locations. The Qvr deposit is approximately 35 feet thick to the south (crossgradient) of the Landfill and approximately 15 to 20 feet thick north (crossgradient) and east (upgradient) of the Landfill.

- **Ice-Contact Deposits (Qvi)** – Deposits similar in texture to unit Qvr but locally containing a much higher percentage of silt intermixed with granular sediments also include lenses and pods of till. This unit is present at MW-5, MW-5A, and the South Kitsap County Transfer Station Well locations, which are crossgradient to the north of the Landfill. The Qvi unit does not extend to the area underlying the Landfill and was not indicated in geologic logs from upgradient, downgradient, and Landfill interior well locations. The Qvi formation ranges in thickness from approximately 30 feet at the South Kitsap County Transfer Station Well to 35 feet thick at MW-5A. A laterally discontinuous zone of perched groundwater occurs on top of the Qvi deposit and well MW-5 is screened in this perched groundwater zone.

- **Till (Qvt)** – Compact very poorly sorted sediment containing sub-rounded to well-rounded clasts; glacially transported and deposited. The Qvt unit was identified in geologic logs for wells throughout the Landfill property. The Qvt unit ranges in thickness from approximately 10 feet thick at MW-5A and MW-3 to approximately 20 feet thick at MW-6, MW-8, and MW-10.

- **Advance Outwash Deposits (Qva)** – Well-bedded sand and gravel deposited by streams and rivers that issued from the leading edge of the advancing ice sheet. Formation is generally unoxidized almost devoid of silt or clay, except near the base of the unit. The Qva unit was identified in geologic logs for wells throughout the Landfill property. The Qva unit contains the uppermost unconfined aquifer and is the geologic unit in which all the monitoring wells at the Landfill are screened, except MW-5, which is screened in a shallower zone of laterally discontinuous perched groundwater. The only well that fully penetrates the Qva unit is the South Kitsap County Transfer Station water supply well (OW-1). The geologic log for this well indicates that the Qva unit is approximately 100 feet thick at this location.

- **Lawton Clay (Qvlc)** – The formations noted above are underlain by a thick sequence of blue clay identified as the Lawton Clay and described below. The Lawton Clay layer is approximately 145 feet thick under the Landfill, based on the geologic log from nearby off-site water supply well OW-3.

- **Olympia Beds (Qob)** – Pleistocene age sand and silt thinly interbedded with some gravel layers and, locally, with abundant organic material; deposited by lowland streams or in floodplain and (or) lacustrine environments. As noted above, many of the water supply wells installed near the Landfill are screened in the Qob formation, which contains the confined deeper aquifer beneath the Landfill.

2.3.2 Local Hydrogeology

Local hydrogeology is depicted in a series of four hydrogeologic cross-sections based on well and test pit logs for on-site Landfill monitoring wells, off-site water supply wells, and on-site tests pits. The alignments for the hydrogeologic cross-sections are depicted on Figure 3 and the four cross-sections A-A' through D-D', are presented in Attachment A.

The geologic units observed in samples from boreholes for the downgradient wells installed during the RI (MW-8 and MW-10) are consistent with the geology observed in boreholes for the nearby older downgradient wells MW-3, MW-6, and MW-7. Geology of the upper approximately 20 feet at each downgradient monitoring well location consists of dense, generally well-graded sand with gravel, which is identified as weathered glacial till. The weathered glacial till layer is underlain by poorly graded fine to medium sand with a trace of gravel and silt and is identified as advance outwash deposits. The upper aquifer at the Landfill is contained within these advance outwash deposits as depicted on the C-C' cross-section in Attachment A.

Geologic logs for all four downgradient monitoring wells, interior wells MW-2 and MW-4, crossgradient well MW-7, and upgradient well MW-1 (cross-sections A-A', B-B', and C-C') confirm that there were no lenses or layers of perched groundwater in the geologic formations above the upper aquifer in which the monitoring wells are screened. In addition, geologic logs indicate that there were no low permeability layers encountered that could potentially form a perched groundwater layer at a depth above the uppermost aquifer.

A shallow perched groundwater zone has only been identified in the boreholes for three wells installed in the north part of the Landfill property: MW-5 (which is screened in the perched zone), MW-5A, and the South Kitsap County Transfer Station Well as depicted on cross-section B-B'. The boring log for Landfill interior well MW-4 indicates wet refuse containing paper and carpet scraps at 3 to 8 feet below ground surface (bgs). The wet refuse does not appear to represent a perched groundwater zone because it is not underlain by a low permeability layer that is capable of perching groundwater. In addition, the boring log for Landfill interior well MW-2, which was drilled at the same time as MW-4, indicates that the refuse encountered was moist, but was not wet and no low permeability layers or perched groundwater zones were encountered in the MW-2 borehole.

Landfill interior monitoring wells MW-4 and MW-2 were drilled in April 1985, several years before the Landfill was capped and the underlying refuse was subject to much greater infiltration rates compared to the current infiltration rates through the engineered low permeability Landfill cap. Therefore, there is no evidence of perched groundwater zones in the geologic units beneath the Landfill and no reason to suspect their presence, especially under the current conditions of significantly limited infiltration through the Landfill cap.

Measured depths to groundwater in monitoring wells at the Landfill vary considerably due to the steep topography of the area. Generally, depth to water is greatest in upgradient well MW-1 and ranged from approximately 68 to 88 feet bgs. Downgradient well MW-6 generally has the shallowest measured depths to water ranging from approximately 14 to 29 feet bgs. Groundwater elevations measured in wells at the Landfill generally range from approximately 246 to 276 feet National Geodetic Vertical Datum of 1929 (NGVD 29), excluding two apparent anomalously low measurements at MW-3 in 2003 and MW-6 in 2011. A time-series plot of measured water level elevations in Landfill wells from 1991 through September 2021 is presented in Attachment B.

The groundwater flow direction in the upper aquifer beneath the Landfill during the September 2022 monitoring event was generally toward the northwest as depicted on Figure 4. Based on the groundwater elevation contours the groundwater flow direction at the Landfill is toward the northwest, with potentially a western component near MW-3 and MW-10. Groundwater elevation contour pattern and flow directions have been consistent throughout all four seasons and over many years of water level measurements. The groundwater flow direction maps demonstrate that well MW-1 is consistently upgradient of the Landfill, wells MW-3, MW-6, MW-8, and MW-10 are downgradient of the Landfill, and wells MW-5A and MW-7 are consistently crossgradient to the Landfill.

2.4 Nature and Extent of Impacted Media

Groundwater, surface water, and landfill gas are routinely monitored at the Landfill. Groundwater and landfill gas have been monitored quarterly and surface water has been monitored annually since 1991. This long-term monitoring has resulted in a large comprehensive database for these media and concentrations of constituents of concern (COCs) established for these media in the RI/FS Report are well understood.

2.4.1 Groundwater

COCs for groundwater at the Landfill are arsenic, iron, manganese, and vinyl chloride. Vinyl chloride was initially identified as a COC in the RI/FS, but it has not been detected at concentrations greater than the cleanup level (CUL) since March 2001. Vinyl chloride, however, will continue to be monitored. Concentrations of the COCs are compared with Washington State Drinking Water Standards (WAC 246-290-310), Washington State Groundwater Quality Standards (WAC 173-200-040) and site-specific CULs. With the notable exception of arsenic, these COCs are only detected at concentrations greater than state standards or site-specific CULs in samples from downgradient wells. Arsenic is routinely detected at concentrations greater than Washington State Groundwater Quality Standards in samples from all downgradient wells MW-3, MW-6, MW-8, and MW-10, crossgradient wells MW-5A and MW-7, and upgradient well MW-1. TRC has provided in this report the last 5 years of all quarterly and annual reports time series graphs for Ecology to evaluate the discontinued sampling of crossgradient wells MW-5A and MW-7.

Time-series plots of concentrations of the four groundwater COCs in samples from Landfill monitoring wells from 1992 through January 2022 and for data generated since implementation of the CAP (March 2015 through January 2022) are included in Attachment C. The full time-series plots (1992–2022) are useful to graphically demonstrate that groundwater quality has improved over time. Because MW-8 and MW-10 were installed in 2010, their datasets are smaller than for other wells in the full time-series plots. The post-CAP (March 2015 – September 2022) time-series plots represent data since implementation of the CAP, which provide a greater level of detail for more recent data that might not be readily seen at the scale required for time-series plots that graph all historical results. The occurrence and nature of each of the four groundwater COCs at the Landfill are summarized below.

2.4.1.1 Arsenic

Arsenic is a naturally occurring metal constituent that is present in native soil and in landfill leachate. Arsenic is present at relatively high concentrations in native soil in western Washington. Arsenic is more soluble in aquifers with geochemically reducing conditions, which are common in groundwater beneath landfills because of depleted oxygen through bacterial degradation of organics in the landfill and in landfill leachate.

Arsenic has been routinely detected at concentrations greater than the Washington State Groundwater Standard of 0.05 micrograms per liter (µg/L) in samples from all Landfill monitoring wells, including upgradient well MW-1 and crossgradient wells MW-5A and MW-7. Arsenic concentrations in samples from Landfill wells have not been greater than the current Washington State Drinking Water Standard of 10 µg/L since a single detection at 11 µg/L in the December 1992 sample from MW-6. The geochemically reducing conditions in the upper aquifer beneath the Landfill increases the solubility of the naturally occurring arsenic present in native soil, which increases arsenic concentrations in groundwater samples from downgradient monitoring wells relative to concentrations in samples from upgradient well MW-1.

Time-series graphs show that arsenic concentrations are commonly greatest in samples from three downgradient wells, specifically MW-6, MW-8, and MW-10, and are commonly at concentrations greater than the site-specific CUL of 1.29 µg/L in samples from MW-10. Arsenic concentrations in samples from downgradient well MW-3 and crossgradient wells MW-5A and MW-7 are consistently less than the site-specific CUL of 1.29 µg/L in post-CAP data. In addition, arsenic concentrations in samples from downgradient wells MW-6 and MW-8 have consistently been less than the site-specific CUL since October 2018 and December 2020, respectively, and exhibit visually and best-fit line decreasing trends on the post-CAP time-series graph for arsenic presented in Attachment C. Arsenic concentrations are lowest in samples from upgradient well MW-1 and downgradient well MW-3 and are sporadically not detected in samples from MW-1.

2.4.1.2 Iron

Iron is a naturally occurring metal constituent that is present in native soil and in landfill leachate. Like arsenic, iron is more soluble under geochemically reducing conditions commonly found in groundwater at landfills. Iron is commonly detected at concentrations greater than its secondary Washington State Groundwater Standard, Washington State and Drinking Water Standard, and site-specific CUL of 300 µg/L in samples from downgradient wells MW-6 and MW-8.

Based on the post-CAP time-series plot iron concentrations ranged from non-detect at a reporting limit of 20 µg/L in most samples from upgradient well MW-1, downgradient well MW-3, crossgradient wells MW-5A, and MW-7 to 1,900 µg/L in the September 2015 sample from downgradient well MW-6. The post-CAP time-series plot shows that iron is routinely detected only in samples from downgradient wells MW-6, MW-8, and MW-10, and is only detected at concentrations greater than its CUL in samples from MW-6 and MW-8. Iron concentrations in samples from all wells, except for data from MW-8, have been less than the CUL since September 2020. In addition, post-CAP data for downgradient wells MW-6 and MW-8 exhibit visually and best fit line decreasing trends on time-series graphs in Attachment C.

2.4.1.3 Manganese

Manganese is a naturally occurring metal constituent that is present in native soil and in landfill leachate. Like iron and arsenic, manganese is more soluble under the geochemically reducing conditions commonly found in groundwater at landfills. Manganese is commonly detected at concentrations greater than its secondary Washington State Groundwater Standard, Washington State Drinking Water Standard, and site-specific CUL of 50 µg/L in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10. Manganese concentrations in all downgradient Landfill monitoring wells, except MW-6, are consistently greater than the MTCA Method B cleanup level of 750 µg/L. Manganese concentrations in samples from downgradient well MW-6 have consistently been less than 750 µg/L since September 2019.

Based on the post-CAP time-series plot, manganese concentrations ranged from non-detect in samples from wells MW-1, MW-5A, and MW-7 to 8,840 µg/L for the March 2018 sample from downgradient well MW-3. The time-series plots show that manganese is only detected in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10 and is consistently at concentrations greater than its CUL in samples from those wells. Manganese concentrations for data from downgradient wells MW-6, MW-8, and MW-10 exhibit visually and best-fit line downward trends. The best-fit trend line for post-cap data from MW-3 is upward; however, manganese concentrations in samples from MW-3 appear to generally decrease since the peak in March 2018 (see Attachment C). In addition, the manganese time-series graphs for the most recent 5 years (2017 to 2021), which is how data are statistically evaluated in quarterly and annual groundwater reports, demonstrate downward manganese concentration best-fit line trends for all wells, including MW-3 (see Attachment D).

2.4.1.4 Vinyl Chloride

Vinyl chloride is a breakdown product formed by the anaerobic degradation of chlorinated volatile organic compounds (VOCs). The presence of chlorinated VOCs at the Landfill is likely from small quantities of household cleaning products containing chlorinated solvents that are contained in the refuse. Historically, vinyl chloride was routinely detected at concentrations greater than the Washington State Groundwater Primary Standard of 0.02 µg/L and the site-specific CUL of 0.29 µg/L. Vinyl chloride has not been detected at a concentration greater than the site-specific CUL in samples from any well since March 2001. In addition, vinyl chloride was never detected at a concentration greater than the Washington State Drinking Water Primary Standard of 2.0 µg/L in samples from any of the Landfill wells.

Based on the post-CAP time-series plot in Attachment C, vinyl chloride concentrations ranged from non-detect in samples from upgradient well MW-1, crossgradient wells MW-5A and MW-7 to 0.11 µg/L for the March 2019 samples from MW-6 and MW-10. The time-series plot for post-CAP implementation data show that vinyl chloride was not detected in samples from any wells since September 2019 until two detections in the December 2021 and June 2022 samples from MW-8 at concentrations of 0.04 and 0.021 µg/L, respectively. In addition, vinyl chloride was not detected in any post-CAP samples from upgradient well MW-1, crossgradient wells MW-5A and MW-7, or downgradient well MW-3.

2.4.2 Surface Water

There are no streams, lakes, ponds, or other natural surface water occurrences at the Landfill. Springs have historically been reported on the private property located immediately west (downgradient) of the Landfill. However, KPHD, KCPW, and their consulting team were unable to obtain permission to access this property during the RI. Therefore, springs were not identified or sampled during the RI/FS and spring sampling is not part of the ongoing monitoring program under the SWHP. A spring was identified on a property farther downgradient of the Landfill and was sampled during 2021 as described in Section 5.5.

A surface water management and conveyance system consisting of engineered drainage channels and culverts were installed during closure activities to drain surface water runoff away from the Landfill and route the water into the stormwater detention pond. The drainage channels comprise a surface water handling system that surrounds the Landfill area. Engineered drainage channels also surround the outside of the perimeter road to prevent runoff from entering the Landfill area and potentially contributing to infiltration into the Landfill. Routing surface water flow to the detention pond attenuates peak surface water flow. The surface water management system at the Landfill was designed and constructed to comply with the requirements of WAC 173-304.

As part of the ongoing quarterly monitoring program, surface water at the Landfill is sampled annually, when present during the March or December monitoring events, from location SW-2. SW-2 is located at the main culvert that discharges into the stormwater detention pond (Figure 2). Surface water samples collected at SW-2 are analyzed for ammonia, nitrate, nitrite, pH (field and laboratory), specific conductance, temperature, and fecal coliform as required by the SWHP.

Surface water samples were collected from SW-2 during December (fourth quarter) sampling events since implementation of the CAP (2015 to 2021). Field and analytical data from the 2015 to 2021 surface water sampling events had no regulatory exceedances for the constituents analyzed or water quality parameters measured in the field.

2.4.3 Landfill Gas

As noted in Section 2.1, Landfill closure included installation of three passive landfill gas flares connected by 6-inch diameter perforated polyvinyl chloride (PVC) piping installed under the low permeability cap. Flares 1, 2, and 3 are monitored for indicators of landfill gas during each quarterly groundwater monitoring event per requirements of the SWHP. The following parameters are measured in the field at all three flares during quarterly monitoring events at the Landfill:

- Methane (percent by volume)
- Lower explosive limit (LEL; percent)
- Oxygen (percent by volume)
- Carbon dioxide (percent by volume)
- Temperature (degrees Celsius)
- Gas pressure (inches of water)

Methane concentrations (by volume) from the three landfill flares during the post-CAP implementation period from 2015 to 2022 are presented on Figure 5. During that time methane has been detected at measurable concentrations in at least one of the three flares during 17 of the 31 landfill gas monitoring events performed from March 2015 through September 2022. Methane measurements range from not detected to a high of 26.2 percent by volume measured in Flare 3 during the December 2017 monitoring event. Generally, the greatest methane concentrations are measured during inclement weather events (falling barometric pressure) during the fourth quarter monitoring event (December).

Many years of evaluation of landfill gas monitoring data from the flares demonstrate that indictors of landfill gas (e.g., the presence of methane and/or carbon dioxide and depressed oxygen concentrations) are more likely to be present in the flares during falling barometric pressure conditions. During periods of falling barometric pressure, landfill gas enters and vents through the flares as subsurface pressure equilibrates with decreasing ambient barometric pressure. Even while venting during decreasing barometric pressures, measured gas pressures in the flares remain very low and are like gas pressure measurements when landfill gas is not present in the flares. This observation is consistent with the low landfill gas production rates expected for a landfill that has been closed for more than 30 years.

During the RI performed in 2010, all three flares were temporarily plugged, allowed to equilibrate, and the trapped landfill gas was sampled for VOCs. The sampling was performed to determine if detectable concentrations of chlorinated VOCs, particularly vinyl chloride, were present in landfill gas and could be impacting groundwater. All samples from the three flares were non-detect for chlorinated VOCs and no further analytical testing of the landfill gas was warranted. Quarterly landfill gas monitoring continues under the SWHP.

There are no landfill gas probes around the perimeter of the Landfill. However, in March 1994, a bar hole survey was performed to investigate potential landfill gas migration. Soil vapor was collected and measured at 34 approximately 3-foot-deep bar hole locations around the perimeter of the Landfill. Methane was not detected in samples from any of the 34 bar hole locations. Oxygen was measured at 21 percent (ambient conditions) in all but one of the bar holes. At bar hole location GS-3, which is next to the northern perimeter road approximately 200 feet east of MW-3, oxygen was measured at 14 percent. The low oxygen measurement can be an indication of landfill gas; however, methane, which is a stronger indicator of the presence of landfill gas, was not detected in the sample from this location in 1994 (CH2M HILL 1994).

A second bar hole survey was performed at the Landfill on January 20 and 21, 2022. Bar holes were performed in two areas, around the perimeter of the Landfill, like the 1994 bar hole survey, and along three transects in the Phase II Area (construction debris area) of the Landfill at the locations shown on Figure 6.

Bar hole measurements were made by driving a 5-foot section of 1-inch diameter steel pipe approximately 3 feet into the soil at the locations shown on Figure 6. The pipe had a crimped and sharpened driving end with perforations in the bottom 1 foot to allow soil gas measurements inside of the perforated end of the pipe. A GEM 2000 landfill gas meter equipped with tubing extending from the meter to the perforated pipe interval was sealed into the driven pipe and used to purge air from the pipe interior. Upon stabilization, soil gas measurements for methane, lower explosive limit (LEL), oxygen, carbon dioxide, and temperature were recorded in the field logbook. Data from the January 2022 bar hole survey are presented in Table 1.

The January 2022 bar hole survey was performed to evaluate subsurface soil gas conditions, specifically to identify areas where methane is present in soil pores, which would indicate reducing (anaerobic and methanogenic) degradation of organic material deeper in the Landfill. If reducing geochemical conditions exist in the Phase II Area, those conditions could increase the solubility, and therefore concentrations, of some naturally occurring metals such as arsenic, iron, and manganese in groundwater.

Methane was not detected in soil gas from any of the 30 perimeter bar hole samples or the 29 bar hole locations arranged in three east-west transects across the Phase II Area of the Landfill. This finding indicates that methanogenic (reducing) geochemical conditions are not present at the locations where soil gas measurements were made during this bar hole survey. In addition, any methane produced in the Phase I Area of the Landfill, which, if present, is vented through three flares, was not detected around the perimeter or in the Phase II Area of the Landfill.

Soil gas at some bar hole locations had slightly depleted oxygen concentrations commonly accompanied by trace concentrations (commonly less than 1 percent) of carbon dioxide. This finding was anticipated because the GEM 2000 landfill gas meter has a significantly more sensitive carbon dioxide sensor compared to field instrumentation available when the 1994 bar hole survey was performed. The presence of slightly depleted oxygen and trace concentrations of carbon dioxide at some locations is likely due to aerobic degradation of decaying vegetation in shallow soil, which is highly vegetated, especially on the soil cover of the Phase II Area of the Landfill.

3.0 REMEDIAL MEASURES

Risk assessments were conducted as part of the RI/FS process to evaluate potential impacts to human health and the environment at and in the vicinity of the Landfill. Risk assessments identified potential source areas of hazardous substances.

The 2014 RI/FS identifies arsenic, iron, manganese, and vinyl chloride as the groundwater COCs for the Landfill. The primary potential exposure route of concern was identified as human ingestion of impacted groundwater from shallow aquifer water supply wells. Groundwater associated with the deeper aquifer (below the Lawton Clay), in which most water supply wells downgradient of the Landfill are completed, is not associated with any human health or ecological risks from the Landfill. The evaluations in the RI/FS also indicated that site-specific COCs in the uppermost aquifer beneath the Landfill posed a negligible risk of adverse effects to ecological receptors in aquatic or terrestrial habitats downgradient of the Landfill.

A Feasibility Study was performed that evaluated and compared three alternative cleanup actions that were identified as being appropriate for groundwater cleanup at the Landfill. The alternatives are listed below:

- Alternative 1 – MNA and Land Use Controls
- Alternative 2 – Low Permeability Geomembrane Cap with MNA and Land Use Controls
- Alternative 3 – *In Situ* Physical/Chemical Treatment: Air Sparging and Complexation

All three alternatives met the minimum requirements for cleanup actions under MTCA except for the requirement to use permanent solutions to the maximum extent practicable. A permanence assessment of the three alternatives was performed and Alternative 1, MNA with Land Use Controls, was the preferred alternative based on the permanence requirement. The cleanup actions associated with the selected remedy are summarized in the following sections.

3.1 Cleanup Actions

The cleanup actions for the Landfill, MNA with Land Use Controls, were selected using the MTCA Feasibility Study process and are defined in the 2014 CAP. The selected cleanup action consists of the following components:

- Preparation and implementation of a *Compliance Monitoring Plan* (CMP).

- Continued quarterly monitoring of monitoring wells MW-1, MW-3, MW-6, MW-8, and MW-10 and annual monitoring at monitoring wells MW-5A and MW-7 and surface water location SW-2 with quarterly and annual reporting.

- Continued inspection, maintenance, and repair of Landfill closure systems, including the cap, drainage ditches, the detention pond, monitoring wells, and the Landfill gas system.

- Continued quarterly monitoring, maintenance, and operation of the Landfill gas system. Reporting landfill gas measurements with the quarterly groundwater reports.

- Institutional controls, specifically, planned preparation of an Environmental Covenant, Land Use Control Implementation Plan, and Notice of Conveyance or Other Transfer of an Interest in the Property upon property transfer.

3.2 Engineering Controls and Post-Closure Care

The existing source control and containment systems that continue to be operated and maintained as a component of post-closure care at the Landfill include the following:

- The Phase I Area of the Landfill was closed with a minimum of 2-foot-thick low-permeability bentonite-amended, vegetated soil cap in accordance with WAC 173-304. The cap is monitored, inspected, and maintained in accordance with the Landfill closure plan and the SWHP.

- The Phase II Area is covered by a minimum of 1 foot of vegetated soil cover. The wastes remain dry and are separated from the uppermost aquifer by 40 to 50 feet of unsaturated soil demonstrating no direct contact between waste and groundwater.

- Installation, inspection, and maintenance of stormwater runoff diversion and control structures (e.g., conveyance ditches and a stormwater detention pond), to reduce precipitation infiltration and potential leachate generation.

- Installation, inspection, maintenance, and monitoring of a passive landfill gas collection system.

3.3 Institutional Controls

Institutional controls currently in place at the Landfill consist of measures implemented by KCPW and those in place due to the Landfill's status as a closed municipal solid waste landfill. The following controls will continue until CULs and other Landfill post-closure criteria are met:

- Signage to identify the presence of the Landfill and restrict access by the public (e.g., "no trespassing" signs).

- Restrictions on the use of the capped landfill surface.

- Fences, locked gates on access roads, perimeter ditches and berms limit access by vehicles and trespassers to the Landfill including fences with locked gates surrounding each of the three landfill gas flares and the stormwater detention pond.

- The Landfill property is listed in County and State records. Water well installation and residential development is restricted within 1,000 feet of the property boundary.

- The Landfill is regulated under Washington State Minimum Functional Standards for Solid Waste Handling (WAC 173-304) and is required to have financial assurance for post-closure operation and maintenance costs.

- Planned preparation of an Environmental Covenant, Land Use Control Implementation Plan, and Notice of Conveyance or Other Transfer of an Interest in the Property upon property transfer. The Environmental Covenant would also be prepared and filed when the cleanup action is complete or when the facility no longer operates under a post-closure permit, whichever occurs first.

3.4 Monitored Natural Attenuation

The selection cleanup action is MNA, which relies on source control and natural attenuation processes to achieve applicable CULs. Source control measures implemented at the Landfill include installation, inspection, and maintenance of a low-permeability bentonite-amended soil cap over the Phase I Area, landfill gas extraction, and maintenance of stormwater controls.

Natural attenuation is the process by which concentrations of chemicals introduced into the environment are reduced over time by a combination of natural physical, biological, and chemical processes. MNA relies on the continuation of site-specific natural attenuation processes to achieve CULs at the conditional point of compliance (CPOC) within a reasonable restoration time frame. Groundwater monitoring of the conditions favorable for those site-specific natural attenuation processes is necessary to demonstrate that natural attenuation is maintained over time at the Landfill.

3.5 Compliance Monitoring Plan

Specific groundwater, surface water, and landfill gas monitoring methods and procedures that are performed under the requirements of MFS, the SWHP, and the CAP are documented in the 2015 *Compliance Monitoring Plan* (CMP; EPI 2015). The CMP integrates all monitoring program requirements into one document that contains, as attachments, a site-specific *Sampling and Analysis Plan* (SAP), *Quality Assurance Plan* (QAP), and *Health and Safety Plan* (HASP) that meet the requirements specified under WAC 173-340-820 and -830. Environmental monitoring at the Landfill is currently being performed in accordance with the CMP and the current SWHP issued by KPHD.

3.6 Cleanup Standards

Cleanup standards for the Landfill consist of three components: (1) COCs, (2) CULs to be achieved for each of the COCs and (3) point of compliance (POC) where the CULs must be achieved. The three components of the cleanup standards are described in the following sections.

3.6.1 Constituents of Concern

Groundwater COCs identified during the RI are arsenic, iron, manganese, and vinyl chloride. These COCs were based on evaluations of long-term groundwater monitoring results for the Landfill. The COCs were selected by comparing analytical results from long-term monitoring to regulatory screening levels. Those COC concentrations that exceed the regulatory screening levels may pose a threat to human health or the environment and were selected as the groundwater COCs. Groundwater samples were analyzed for these COCs, as well as the full WAC 173-351-990 Appendix III constituent list, which is the list of hazardous inorganic and organic constituents in the Municipal Solid Waste Landfill regulations.

3.6.2 Cleanup Levels

Site-specific CULs were developed for the COCs according to the requirements of the MTCA regulations, which stipulate that CULs be "at least as stringent as all applicable state and federal laws" (RCW

70.105D.030 [2][e]; Ecology 2007). The Final RI/FS Report described the process for evaluating the indicator hazardous substances and identified the following remaining COCs that must be addressed by the selected cleanup action at the Landfill (Parametrix 2014a):

- Arsenic = 1.29 µg/L
- Iron = 300 µg/L
- Manganese = 50 µg/L
- Vinyl chloride = 0.29 µg/L

Although vinyl chloride was initially identified as a COC for the RI/FS, vinyl chloride has not been detected at a concentration that exceeded the CUL since a March 2001 sample from downgradient well MW-6 with a vinyl chloride concentration of 0.355 µg/L. Vinyl chloride, however, will continue to be monitored.

3.6.3 Conditional Point of Compliance

The POC is the point or points of compliance where CULs established in accordance with WAC 173-340-720 through 173-340-760 shall be attained. The standard groundwater POC is defined by WAC 173-340-720(8) for all sites as the groundwater throughout the site from the uppermost level of the saturated zone extending vertically to the lowest depth that could potentially be affected by the site. However, WAC 173-340-720(8)(c) allows for a CPOC where it is not practicable to meet the CUL throughout the site within a reasonable restoration time frame. The regulation requires that the CPOC shall be as close as practicable to the source of hazardous substances and shall not extent beyond the property boundary.

The Landfill meets the conditions for a CPOC because leachate will continue to be released from the Landfill for years thereby creating an ongoing source of contaminants and maintaining reducing geochemical conditions that are anticipated to impact groundwater under the capped or covered refuse. The source material in the landfill waste will not be completely mitigated without complete removal of all refuse at the Landfill; therefore, it will not be practicable to meet the CULs throughout the Landfill within a reasonable restoration time frame.

As noted in the CAP, the upper aquifer at the Landfill property boundaries is appropriate as the Landfill CPOC. Based on the west-northwest regional groundwater flow direction established during the RI, the western property boundary is a downgradient boundary, the north and south boundaries are roughly parallel to upper aquifer groundwater flow, and the eastern boundary is upgradient. Monitoring wells generally located along the downgradient western property boundary (MW-3, MW-6, MW-7, MW-8, and MW-10) are close to the refuse limits and will serve as the groundwater monitoring points at the CPOC.

4.0 EFFECTIVENESS OF CLEANUP ACTIONS

This section discusses the effectiveness of the engineering and institutional controls that have been implemented at the Landfill.

4.1 Effectiveness of Engineering Controls

The effectiveness of engineering controls at the Landfill is based on their ability to limit the potential for exposures to hazardous substances and contribute to the attainment of site-specific cleanup standards. As noted in Section 3.2, existing engineering controls that have been implemented at the Landfill are:

- a low-permeability 2-foot-thick bentonite-amended, vegetated soil cap over the Phase I Area (municipal waste area) of the Landfill
- a minimum 1-foot-thick vegetated soil cover over the Phase II Area (construction debris area) of the Landfill
- stormwater runoff diversion and control structures
- a passive landfill gas collection system

The effectiveness of the engineering controls was based on evaluations of the results of inspection, maintenance, and periodic monitoring of the performance and condition of the existing engineering controls at the Landfill.

4.1.1 Landfill Cap and Stormwater Collection and Conveyance System

Maintenance of the Landfill cap includes implementation of weed control and semiannual mowing, typically performed in June and October. Vegetation (e.g., weeds, shrubs, and small trees), whose roots could potentially compromise the integrity of the Landfill cover are removed. KCPW performs monthly inspections of the Landfill cap, stormwater conveyance systems, perimeter road, and Landfill gas flares. KPHD conducts routine quarterly inspections of the Landfill cap and associated site controls with a representative from KCPW. Minor issues identified during these inspections are commonly performed as soon as practicable. If more significant repairs are required, they are performed by KCPW, or a contractor hired by KCPW. The results of the repairs, upgrades, or modifications are reported in annual monitoring reports provided to KPHD and Ecology following each fourth quarter monitoring event.

In 2019 the KCPW Roads Engineering survey group established permanent monitoring points, designated FM1 through FM25, on the surface of the closed Landfill at locations shown on topographical maps presented in Attachment E. The purpose of the permanent points is to monitor possible movement of the surface of the closed landfill over time. In December 2020, Kitsap County surveyors re-surveyed the permanent monitoring points at Landfill. Minor differences between the original 2019 survey coordinates and elevations relative to the 2020 survey coordinates and elevations are within the precision of the instrumentation and operators. This finding demonstrates no evidence of measurable movement of the surface of the closed Landfill.

Inspection reports issued by KPHD from 2014 to 2020 indicated that the Landfill cap and stormwater conveyance system were functional over that period and the engineering controls inspected comply with landfill closure requirements in WAC 173-304. The Landfill cap remains in good condition with no significant recent settlement, erosion, or damage reported. Stormwater drainage ditches at the stormwater detention pond were inspected and reported to be good condition and properly maintained. Inspection documents indicate that the Landfill cap and stormwater collection and conveyance systems have been well-maintained, repaired as needed, and are effective at limiting the amount of infiltration that could contribute to leachate generation at the Landfill. Copies of the KPHD inspection forms and 2019 versus 2020 permanent monitoring point survey coordinates are presented in Attachment E.

The effectiveness of the cap and stormwater conveyance system at reducing leachate generation caused by infiltration through the wastes is evaluated by groundwater monitoring. Groundwater monitoring at the Landfill is conducted quarterly at five monitoring wells (MW-1, MW-3, MW-6, MW-8, and MW-10). Two additional crossgradient wells (MW-5A and MW-7) are sampled during the annual groundwater monitoring event, which is performed during the fourth quarter of each year. In addition, surface water is sampled at SW-2 annually, during the first (March) or fourth (December) sampling event. Groundwater monitoring data are compared to site-specific CULs established in the CAP for the COCs arsenic, iron, manganese, and vinyl chloride. Concentration trends are plotted on time-series plots for the groundwater COCs and for other constituents that are analyzed as required by the SWHP. Annual reports include additional data evaluations, yearly summaries, and surface water sampling data. Quarterly and annual reports are provided to Ecology and KPHD following the reporting schedule in the SWHP.

The Phase I Area of the Landfill has a 2-foot-thick bentonite-amended soil cap with a permeability of $1x10^{-6}$ centimeters per second (cm/sec) or less and was tested during and following emplacement to ensure that it met design criteria. The Phase I Area cap effectively reduces the volume and rate of infiltration through the waste, although it does not fully prevent all infiltration. The vegetated soil cap over the Phase II Area was not designed or intended to reduce infiltration because the nature of the waste in the Phase II Area is construction debris and leaching of contaminants is not anticipated.

Both the bentonite-amended soil cap for the Phase I Area and the vegetated soil cap for the Phase II Area met closure requirements and design criteria at the time of closure and continue to function as designed. Time-series graphs for vinyl chloride (Attachment C) document that there are no exceedances of the site-specific CUL since 2001 in a sample from MW-6. This significant improvement and frequency of non-detections for vinyl chloride demonstrates that the Landfill caps are functioning as designed and are effective at reducing infiltration and leaching of contaminants.

Elevated concentrations of metals (i.e., arsenic, iron, and manganese) in groundwater are the result of increased solubility of naturally occurring minerals due to reducing (anaerobic) geochemical conditions in the upper aquifer under the Landfill. The reducing geochemical conditions in the aquifer are caused by breakdown of organic matter in the refuse contained within the Landfill. Reducing geochemical conditions will continue until the organic matter present in the refuse has been significantly decomposed.

4.1.2 Landfill Gas Flares

The three passive Landfill gas flares are monitored quarterly for indicators of Landfill gas to evaluate the presence of methane and carbon dioxide and depressed oxygen concentrations. The flares are measured for the following parameters:

- Methane (percent LEL)
- Oxygen (percent by volume)
- Carbon dioxide (percent by volume)
- Gas pressure (inches of water)

Results of the Landfill gas flare monitoring are presented with groundwater and surface water data in quarterly and annual reports. Post-CAP implementation methane concentration data measured at the three flares are presented on Figure 5.

Methane has been detected at measurable concentrations in at least one of the three flares during 17 of the 31 landfill gas monitoring events performed from March 2015 to September 2022. Methane measurements range from not detected to a high of 26.2 percent by volume measured in Flare 3 during the December 2017 monitoring event.

Pressure measurements in the flares are typically in the 0.00 to 0.03 inches of water range during most quarterly monitoring events. A pressure measurement of 0.48 inches of water was recorded during the March 2016 monitoring event although methane was not detected at that time indicating that Landfill gas was not present during that measurement event. Sporadic detections of methane and zero to low pressure measurements in all flares is consistent with conditions expected at the late stages of a closed landfill. Landfill gas generation rates are expected to continue to decline asymptotically because the Landfill is in the tail end of the Landfill gas generation curve.

4.1.3 Water Quality Monitoring Networks

Water quality monitoring at the Landfill is conducted in accordance with the CMP and the SWHP and is reported quarterly. Fourth quarter monitoring results are included with the more comprehensive data evaluations presented in the annual report. Groundwater and surface water monitoring networks for the Landfill are depicted on Figure 2 and are described below.

- **Quarterly Groundwater Monitoring Well Network:** This network consists of upgradient monitoring well MW-1 and downgradient monitoring wells MW-3, MW-6, MW-8, and MW-10. Samples from quarterly monitoring wells are measured or analyzed for the following:

  Field Parameters

Water level	Temperature
Oxidation reduction potential	pH
Dissolved oxygen	Turbidity
Specific conductance	

  Laboratory Analyses

Potassium	Dissolved zinc	Nitrate, nitrite, and ammonia
Carbonate	Dissolved manganese	Chemical oxygen demand
Chloride	Dissolved barium	Sulfate
Total organic carbon	Bicarbonate	Total coliform
Dissolved arsenic	Sodium	Volatile organic compounds
Dissolved iron	Calcium	

- **Annual Groundwater Monitoring Well Network:** This network consists of the quarterly groundwater monitoring network listed above plus crossgradient monitoring wells MW-5A and MW-7. Annual monitoring is performed during the December quarterly event. For the annual monitoring event, upgradient and downgradient monitoring wells continue to be analyzed for the measured and analyzed for the list above. Samples from crossgradient wells MW-5A and MW-7 are measured and analyzed for the reduced list below:

Field Parameters	Laboratory Analyses
Water level	Dissolved arsenic
Oxidation-reduction potential (ORP)	Dissolved iron
Dissolved oxygen (DO)	Dissolved manganese
Specific conductance	Vinyl chloride
Temperature	
pH	
Turbidity	

- **Annual Surface Water Monitoring:** Sample location SW-2 at the outfall to the stormwater detention pond is sampled annually between January and March or November and December and is commonly performed as part of the December or March monitoring event. Station SW-2 is measured and analyzed for the following parameters and constituents:

Field Parameters	Laboratory Analyses
Temperature	Fecal coliform
pH	Nitrate-nitrogen
Specific conductance	

- **Off-Site Water Supply Well and Seep Monitoring:** In addition to the on-site groundwater monitoring wells, KCPW, in coordination with KPHD, periodically samples off-site water supply wells. The off-site well network includes the water supply well for the transfer station and water supply wells on nearby residential properties. Locations of the off-site water supply wells and seep are shown on Figure 3. An offsite well owner can request that their domestic water supply well be sampled by the County; however, the County will collect samples of the well no more than once annually. Furthermore, the following wells: OW-3, OW-5, G.A. Pierson, and Well#4 that draw water from the deeper aquifer will not be sampled. These wells are separated from the uppermost aquifer by a thick dense clay layer and are not hydraulically connected to the upmost aquifer beneath the Landfill.

The off-site wells are measured and analyzed for the following parameters and constituents:

Field Parameters	Laboratory Analyses
ORP	Dissolved arsenic
DO	Dissolved iron
Specific conductance	Dissolved manganese
Temperature	Vinyl chloride
pH	
Turbidity	

Some of the downgradient monitoring wells at the Landfill exhibit site-specific CUL exceedances of some of the inorganic COCs (e.g., arsenic, iron, manganese) and these elevated concentrations likely extend beyond the property boundary. KCPW has worked in cooperation with KPHD and nearby property owners to sample off-site water supply wells and seeps downgradient of the Landfill to further delineate the extent of elevated inorganic COCs. Access to potential seeps on the parcel immediately downgradient of the Landfill has not been granted by the current property owner. However, other off-site groundwater samples have been obtained from other downgradient wells and a seep. Data from off-site water supply wells and seep are presented and described in Section 5.5.

4.2 Institutional Controls

Institutional controls have been implemented at the Landfill to limit the potential for human and ecological exposures to hazardous substances. Institutional controls can be physical barriers, warning signs and notice, prohibitions on activities that potentially damage the cap or other engineering control structures, land use restrictions on the property or resources (e.g., prohibit groundwater use) and maintenance requirements for engineering controls and monitoring systems.

4.2.1 Existing Institutional Controls

Access to the Landfill and structures such as flares, wells, and the stormwater detention pond is restricted by physical barriers and signage. There are two roads that access the Landfill, one from the north adjacent Recycling and Garbage Facility that is separated by a barbed-wire-topped chain link fence with a locked gate, and one from Bandix Road Southeast that is controlled by a locked gate. Access to the Landfill by vehicle is further restricted by heavy vegetation, berms, and steep slopes surrounding the Landfill area. In addition, the three Landfill flares and the stormwater detention pond are each fully surrounded by barbed-wire-topped chain link fences with locked gates. Signage to identify the presence of the Landfill and restrict access by the public (e.g., “no trespassing” signs) is present on the fence separating the Landfill from the Recycling and Garbage Facility, which is only accessible to the public during operating hours. Signage is also present on the gate and along the road at the Bandix Road Southeast entrance.

The perimeter road surrounding the Landfill has deep rock-lined drainage ditches on both sides that reduce the potential for vehicles to drive onto the Landfill cap, should they get past the locked gates, The cap, stormwater detention pond, and drainage ditches are routinely inspected by KCPW and KPHD and repairs are made to damaged institutional controls. Monitoring wells are protected by locked steel monuments set in concrete and protected by steel bollards set in concrete where appropriate. The wells and their protective systems are inspected during every quarterly monitoring event. The Landfill gas flares, and their surrounding fences, gates, and locks are also inspected during quarterly monitoring events. Repairs to monitoring wells, flares, and their protective structures are made upon discovery when possible or soon thereafter if the repair cannot be completed at that time.

The Landfill property is listed in County and State records and water well installation and residential development is restricted within 1,000 feet of the property boundary. The Landfill is regulated under

Washington State Minimum Functional Standards for Solid Waste Handling (WAC 173-304) and is required to have financial assurance for post-closure operation and maintenance costs.

KPWD plans to prepare an Environmental Covenant, Land Use Control Implementation Plan, and Notice of Conveyance or Other Transfer of an Interest in the Property upon property transfer. The Environmental Covenant would also be prepared and filed when the cleanup action is complete or when the facility no longer operates under a post-closure permit, whichever occurs first.

4.2.2 Evaluation of the Effectiveness of Institutional Controls

Institutional controls have effectively protected the Landfill cap, monitoring wells, flares, and stormwater detention pond because no damage, other than normal wear and tear, has been noted during inspections. Minimal evidence of trespassing has occurred on the property during the post-CAP implementation period. There was an attempt to cut the salal bushes in the surrounding forest and one attempt to set up a tent on the adjacent property. Both minor incidents were noted by a Kitsap County employee while the trespasser was present; in both cases the trespasser was immediately directed to depart. No evidence of trespassing such as tire ruts and tracks, vandalism, or the presence of trash, was noted at the Landfill during the post-CAP implementation period.

5.0 DATA EVALUATIONS

Groundwater monitoring data evaluations in support of continuing the cleanup actions described in the approved CAP are presented in the following sections.

5.1 Current and 5-Year Compliance Summary

A summary table of the lower- and upper-95 percent confidence limits (LCL and UCL) for groundwater COCs at the Landfill is presented in Table 2. The statistical evaluations are for the most recent 5 years of data, including the September 2022 sampling event, which is consistent with the statistical evaluation process used for quarterly and annual monitoring reports for the Landfill.

5.1.1 Arsenic

- Both the LCL and UCL are less than the site-specific CUL of 1.29 µg/L for dissolved arsenic in data from upgradient well MW-1, downgradient wells MW-3 and MW-6, and crossgradient wells MW-5A and MW-7. This finding indicates statistical attainment of regulatory compliance for arsenic at these wells.

- Both the LCL and UCL are greater than the site-specific CUL for dissolved arsenic in data from downgradient well MW-10 indicating a statistical exceedance of the CUL for arsenic at MW-10.

- The UCL is greater than the site-specific CUL for dissolved arsenic in data from downgradient well MW-8 but the LCL is not. This does not indicate statistical regulatory compliance nor exceedance, but the data should continue to be monitored.

5.1.2 Iron

- Both the LCL and UCL are less than the site-specific CUL of 300 µg/L or there were too few detections for a statistical evaluation for dissolved iron in upgradient well MW-1, downgradient wells MW-3 and MW-10, and crossgradient wells MW-5A and MW-7. This indicates statistical attainment of regulatory compliance for iron at these wells.

- The LCL is less than the site-specific CUL but the UCL is greater for dissolved iron data from downgradient wells MW-6 and MW-8. This does not indicate statistical regulatory compliance nor exceedance, but the data should continue to be monitored.

5.1.3 Manganese

- Both the LCL and UCL are less than the site-specific CUL of 50 µg/L or there were too few detections for a statistical evaluation for dissolved manganese in upgradient well MW-1 and crossgradient wells MW-5A and MW-7. This indicates statistical attainment of regulatory compliance for manganese at these wells.

- Both the LCL and UCL are greater than the site-specific CUL for dissolved manganese in data from downgradient wells MW-3, MW-6, MW-8, and MW-10 indicating statistical exceedances of the CUL for manganese at those four downgradient wells.

5.1.4 Vinyl Chloride

- There were too few detections of vinyl chloride for a statistical evaluation or both the LCL and UCL were lower than the 0.02 µg/L reporting limit in all wells except downgradient well MW-8. For MW-8 data, both the LCL and UCL are less than the site-specific CUL of 0.29 µg/L. This indicates statistical attainment of regulatory compliance for vinyl chloride at all monitoring wells in the quarterly and annual monitoring well networks.

5.1.5 Geochemical Indicators

The presence of elevated concentrations of arsenic, iron, and manganese in some downgradient wells is caused by reducing geochemical conditions in the aquifer under the Landfill. The field parameter data DO and ORP are important indicators of those geochemical conditions. Time-series graphs of DO and ORP measurements in Attachment F provide an indication of changes to geochemical conditions in the aquifer at the Landfill.

DO concentration trends for the post-CAP period (2015 to 2022) appear to be flat, slightly decreasing in all wells, except for crossgradient wells MW-5A and MW-7. In these wells, the DO concentrations are increasing, indicating a trend to more oxidizing geochemical conditions in crossgradient groundwater and stable to an apparent slight downward trend toward more reducing (anaerobic) conditions in all other wells, including upgradient well MW-1.

ORP measurement trends for 2015 to 2022 are increasing in data from all wells, including the downgradient wells. The ORP trends are stronger and more pronounced than the DO trends and indicate that geochemical conditions are trending toward more oxidizing (aerobic) conditions. Continuation of these increasing ORP trends should result in lower concentrations of arsenic, iron, and manganese in groundwater at the Landfill due to reduced solubility.

5.2 Trend Analysis Summary

Concentration trends for constituents analyzed or measured in groundwater samples from the Landfill are evaluated for trends using time-series plots and the Mann-Kendall test for trend. Time-series plots provide a visual indication of concentration trends and provide a convenient graphical means of delineating seasonal trends and large differences in concentration between upgradient and downgradient wells and can be used to readily identify data that exceed regulatory levels. Historical data are presented as two time-series plots for each of the four COCs in Attachment C (full time-series plots from 1992 to present and post-CAP time-series plots from 2015 to present).

The full time-series plots depicting all quarterly data from 1992, when groundwater monitoring was initiated at the Landfill, to the present are useful to graphically demonstrate that groundwater quality has improved over time. Because MW-8 and MW-10 were installed in 2010, their datasets are smaller than for other wells in the full time-series plots. The post-CAP time-series plots present data from 2015 through 2022 and provide a greater level of detail than is readily seen at the scale required for full time-series plots. Applicable Washington State Drinking Water and Groundwater regulatory levels and site-specific CULs are shown graphically on each of the time-series plots. Linear best-fit trend lines are shown on the recent time-series plots for COC data that exceed site-specific CULs.

The Mann-Kendall trend test is used to determine if upward or downward data trends graphically presented in time-series plots are statistically significant at a greater than 95 percent confidence level. The Mann-Kendall trend test was applied to the most recent 5-year period of data, which is consistent with the statistical methods and procedures used for quarterly groundwater monitoring reports for the Landfill. Mann-Kendall trend test results for the most recent 5 years of COC data are presented in Table 3.

In addition to Mann-Kendall trend test results, there are visually apparent concentration trends that do not meet the statistically rigorous threshold of the 95 percent confidence level for Mann-Kendall but are clearly trends that are readily apparent on the time-series graphs. To capture and quantify the visually apparent trends best-fit linear trend lines were added to the time-series plots presented in Attachment C, when appropriate. Mann-Kendall test for trend and best-fit linear trend results for the four groundwater COCs are described below.

5.2.1 Arsenic

- Post-CAP data indicate dissolved arsenic concentrations from three downgradient wells, MW-6, MW-8, and MW-10 exceeded the site-specific CUL during one or more monitoring events. Upgradient well MW-1, downgradient well MW-3, and crossgradient wells MW-5A and MW-7 had no CUL exceedances for dissolved arsenic.

- Best-fit trend lines for post-CAP data from downgradient wells MW-6, MW-8, and MW-10 indicate decreasing concentration trends for MW-6 and MW-8 and an increasing trend for MW-10. These trends meet the Mann-Kendall 95 percent confidence threshold as noted in Table 3.

- The full 1992 to 2022 time-series plot for dissolved arsenic demonstrates decreasing best-fit trends in concentrations in samples from downgradient wells MW-6 and MW-10.

- Mann-Kendall test for trend results indicate the following statistical trends for dissolved arsenic:

  - Statistically significant downward trends for dissolved arsenic in data from upgradient well MW-1 and downgradient wells MW-6 and MW-8.

  - A statistically significant increasing trend in data from downgradient well MW-10.

  - No statistically significant trends in data from downgradient well MW-3 and crossgradient wells MW-5A and MW-7.

5.2.2 Iron

- Post-CAP data indicate dissolved iron concentrations from two downgradient wells, MW-6 and MW-8 exceeded the site-specific CUL during multiple monitoring events. The remaining five wells had no CUL exceedances for dissolved iron.

- The trend lines for post-CAP data from downgradient wells MW-6 and MW-8 indicate decreasing dissolved iron concentration trends for MW-6, MW-8, and MW-10. These trends also meet the Mann-Kendall 95 percent confidence threshold, indicating that statistically significant downward concentration trends for iron in data from MW-6, MW-8, and MW-10 (Table 3).

- The Mann-Kendall test for trend results for data from MW-1, MW3, MW-5A, and MW-7 indicate no statistically significant trends for dissolved iron.

- The full 1992 to 2022, time-series plot for dissolved iron demonstrates a visually apparent decrease in concentrations in samples from downgradient well MW-6 and an increasing trend in downgradient well MW-8.

5.2.3 Manganese

- Post-CAP data indicate dissolved manganese concentrations from downgradient wells, MW-3, MW-6, MW-8, and MW-10 exceeded the site-specific CUL during one or more monitoring events. The remaining three wells had no CUL exceedances for dissolved manganese.

- The trend lines for post-CAP data from downgradient wells MW-6 and MW-8 indicate nearly flat to slightly increasing dissolved manganese concentration trends. The trend line for MW-10 is decreasing. The trend line for MW-3 is increasing consistent with the full time-series plot for MW-3. However, concentration trendlines for manganese for the most recent 5 years, which is the period for which data are statistically evaluated in quarterly and annual reports, are all decreasing for downgradient wells, including MW-3, as presented in Attachment D.

- Mann-Kendall test for trend results indicate the following statistical trends for dissolved manganese (Table 3):

  - Statistically significant decreasing concentrations in data from MW-3, MW-6, and MW-8.

  - Mann-Kendall test for trend results for data from MW-1, MW-5A, MW-7, and MW-10 indicate no statistically significant trends for dissolved manganese.

- The full 1992 to 2022 time-series plot for dissolved manganese demonstrates a strong visual and best fit trend line decrease in concentrations in samples from downgradient well MW-6, a moderate decrease in concentrations in samples from downgradient well MW-10, and an increase in concentrations in samples from downgradient well MW-3.

5.2.4 Vinyl Chloride

- Post-CAP data indicate none of the detected concentrations of vinyl chloride exceeded the site-specific CUL during any of the monitoring events. The site-specific CUL for vinyl chloride has not been exceeded since March 2001 in a sample from MW-6.

- Although all vinyl chloride concentrations are considerably less than the CUL there were enough detections to add trend lines for MW-6, MW-8, and MW-10. Trend lines for post-CAP data from downgradient wells MW-6, MW-8, and MW-10 are depicted and indicate slightly decreasing (MW-8) to very slightly increasing (MW-6 and MW-10) vinyl chloride concentration trends. None of these nearly flat trends meets the Mann-Kendall 95 percent confidence threshold. In addition, except for detections of 0.04 and 0.021 µg/L in samples from MW-8 in December 2021 and June 2002, respectively, vinyl chloride has not been detected in samples from any of the Landfill monitoring wells since September 2019.

- Mann-Kendall test for trend results indicate the following statistical trends for vinyl chloride (Table 3):

  - Statistically significant decreasing concentrations in data from MW-6.

- o Mann-Kendall test for trend results for data from MW-1, MW-3, MW-5A, MW-7, MW-8, and MW-10 indicate no statistically significant trends for vinyl chloride.

- The full 1992 to 2022 time-series plot for vinyl chloride demonstrates strong visual and best fit trend line decreases in concentrations in samples from downgradient wells MW-3 and MW-6. These decreasing concentration trends appear to continue in more recent data from MW-3, which has been consistently non-detect during 2015 to 2022.

5.3 Summary of CAP Effectiveness

Time-series plots for groundwater COCs at the Landfill indicate that in general, COC concentrations are stable (nearly flat trend lines) or continue to decline in most wells with statistical CUL exceedances based on the confidence limit evaluations summarized in Table 2 (Attachment C). The only instance of an increasing Mann Kendall trend for a COC with a statistically significant CUL exceedance is dissolved arsenic in data from downgradient well MW-10 (Table 3).

As demonstrated by time-series plots presented in Attachment C, most notably the full time-series plots from 1992 to 2022, concentrations of COCs in groundwater have generally decreased significantly in most wells as noted below.

- Dissolved arsenic concentrations have decreased significantly in samples from downgradient wells MW-6 and MW-8 and have been less than the site-specific CUL in samples from MW-6 and MW-8 since October 2018 and December 2020, respectively. The 95 percent confidence intervals for arsenic concentrations statistically meet the site-specific regulatory level of 1.29 µg/L in data from all wells except MW-8 and MW-10 (Table 2). Arsenic data currently trend toward meeting the regulatory level in data from MW-8 (downward Mann-Kendall trend as noted in Table 3).

- Exceedance of the upper 95 percent confidence limit for dissolved iron is limited to MW-6 and MW-8. However, the lower 95 percent confidence limit for dissolved iron in data from MW-6 and MW-8 is less than the regulatory level of 300 µg/L. In addition, decreasing dissolved iron concentrations in data for MW-6 and MW-8 are readily apparent and supported by decreasing best fit trend lines on the time-series plots, which is supported by statistically significant downward trends in the Mann-Kendall trend results for data from MW-6, MW-8, and MW-10.

- Dissolved manganese concentrations in MW-3 peaked in March 2018 and generally decreased since then with a short-term increase in June 2020. However, the trend line for post-CAP dissolved manganese data indicates an upward trend for MW-3 Dissolved manganese concentrations in MW-6 have decreased significantly relative to data from the 1990s and early 2000s and remain relatively stable as indicated by a nearly flat to slightly decreasing trend line on the recent time-series plot (Attachment D). Dissolved manganese concentration trend lines for MW-8 and MW-10 are decreasing slightly in the time-series graph for 2015 to 2021.

- There has not been an exceedance of the site-specific CUL for vinyl chloride since March 2001 in a sample from MW-6. In addition, a statistically significant decreasing concentration trend for vinyl chloride is noted in the most recent 5 years of data for downgradient well MW—6 (Table 3). Vinyl chloride should remain non-detect or sporadically detected at concentrations less than the site-specific CUL because of the effectiveness of the cleanup actions (engineering and institutional controls) as well as continued natural attenuation processes.

5.4 Inorganic Constituents Affected by Geochemical Conditions

The presence of elevated concentrations of dissolved arsenic, iron, and manganese in groundwater is attributable to reducing geochemical conditions caused by ongoing bacterial breakdown and metabolism of carbon sources in the municipal waste present in the Landfill. This process consumes much of the available oxygen in the subsurface and DO in groundwater at a higher rate than it is replenished and results in reducing (anaerobic) geochemical conditions in the aquifer. The reducing geochemical conditions favor anaerobic bacterial populations (including iron reducing bacteria) and increase the solubility of some naturally occurring metals, most notably arsenic, iron, and manganese, all of which are COCs for the Landfill. These metals are commonly present at high concentrations in landfill leachate and in groundwater under and immediately downgradient of landfills.

Time-series plots for the geochemical parameters DO and ORP are presented in Attachment F. The full and recent time-series plots for DO show a clear difference in measured DO concentrations between the downgradient wells (generally lower DO), and the upgradient and crossgradient wells (generally higher DO). A similar differentiation between downgradient wells and the upgradient and crossgradient wells is observable on the ORP time-series plots. Time-series plots for ORP show that downgradient wells have lower, sometimes negative ORP measurements, indicating reducing geochemical conditions. Upgradient and crossgradient wells have higher ORP measurements, indicating more oxidizing (aerobic) geochemical conditions. Downgradient well MW-3 deviates from this pattern; it has high ORP measurements similar to measurements in the upgradient and crossgradient wells despite low DO measurements that are similar to measurements in the other downgradient wells.

Geochemical conditions in the aquifer continue to trend toward more oxidizing and aerobic based on time-series graphs for ORP, which indicate upward visual and best fit line trends in measurements from all wells. If the increasing ORP trends continue, geochemical conditions in the aquifer will become more oxidizing and will decrease the solubility of naturally occurring arsenic, iron, and manganese, which is expected to result in lower concentrations of those COCs in groundwater.

Because the source material (refuse) will not be completely mitigated without complete removal of all refuse at the Landfill, it is not practicable to meet the CULs for arsenic, iron, and manganese throughout the Landfill or immediately downgradient of the Landfill within a reasonable restoration time frame. Natural recharge from precipitation to the aquifer in the downgradient area to the west of the Landfill is expected to increase DO concentrations and ORP values and restore natural groundwater geochemical conditions approximating those noted in upgradient and crossgradient wells, resulting in decreased concentrations of arsenic, iron, and manganese.

Installing an impermeable cap over the Landfill would reduce infiltration of water through the refuse. However, the impermeability cap would also reduce the rate of oxygen replenishment to the aquifer by decreasing soil gas exchange during barometric pressure changes and by further reducing infiltration and recharge of oxygenated precipitation to the aquifer. The addition of an impermeable cap could potentially make geochemical conditions of the aquifer more reducing and, therefore, more likely to have increased concentrations of naturally occurring arsenic, iron, and manganese in groundwater.

5.5 Off-Site Water Supply Wells and Seep

The lateral extent of elevated dissolved arsenic, iron, and manganese concentrations in groundwater can be approximated by the location of off-site downgradient and crossgradient water supply wells, screened in the upper aquifer, which were historically sampled in 1995 and 1997 and during the RI in 2010 to 2011. In the September 5, 2014, opinion letter, Ecology concluded that contamination likely extends beyond the Landfill parcel and that the Site was not fully characterized outside the Landfill parcel. Ecology acknowledged that the sampling of off-site drinking water wells provides some characterization of off-site downgradient groundwater conditions.

As part of the investigative work associated with this report, Ecology's well database was researched for new water supply wells installed downgradient (west) of the Landfill. Review of Ecology's well database identified four water supply wells that were installed downgradient of the Landfill since the RI was performed in 2010 to 2011. Three of the four wells are completed in the deeper aquifer, which is not hydraulically connected to the upper aquifer beneath the Landfill and in which the Landfill monitoring wells are screened. Information for the four new wells is summarized below:

Well Owner on Well Log	Address on Well Log	Parcel Number	Well Total Depth (feet)	Screened or Open Interval (feet)
Leo & Karen Pierson Trust	2420 Burley Olalla Road	012201-1-031-2009	295	288 – 293.5
Detrick Jones	Olympic Drive Southeast	012201-2-032-2006	260	252 – 258
Jeff Himenes & Christine Morrow	Olympic Drive Southeast	012201-2-031-2007	257	250.7 – 256
Patrick Timmons and Karen Aleccia	13399 Olympic Drive Southeast	012201-1-005-2001	45	Unknown

The locations of historical and recent off-site well and seep sample locations are depicted on Figure 3. Available well logs for historical and recent off-site well that have been sampled are presented in Attachment G. A well log was not available for the uppermost aquifer well installed on the Timmons and Aleccia property (Parcel 012201-1-005-2001) located at 13399 Olympic Drive Southeast. The homeowner reported a total well depth of 45 feet bgs and an unknown screened interval.

Most of the off-site water supply wells installed downgradient of the Landfill are completed in the deeper confined aquifer. The deeper aquifer is separated from the upper aquifer beneath the Landfill by approximately 145 feet of dense low-permeability clay (the Lawton Clay formation) at well location OW—3, approximately 190 feet at OW-5, and approximately 90 feet at Well #4 (see cross-section D-D' in Attachment A). Therefore, groundwater data from off-site wells completed in the deeper aquifer are not representative of downgradient water quality potentially impacted by the Landfill. The focus of additional off-site wells for sampling should be for wells installed in the upper aquifer and seeps in parcels downgradient (west) of the Landfill. One additional off-site well and an off-site seep, both located at 13399 Olympic Drive Southeast, were added to the inventory of off-site wells to be sampled. Based on the topographic contours documented on the Kitsap County Parcel Viewer, seep OS-01, is at an elevation of approximately 205-210feet (National Geodetic Vertical Datum, 1929 [NGVD 29]). The seep elevation is lower than groundwater elevations measured in downgradient wells at the Landfill, which have recently been at approximately 250 to 260 feet NGVD 29 (see Attachment B), demonstrating that seep OS-01 is hydraulically downgradient from upper aquifer groundwater at the Landfill. Historical seep sampling locations OS-02 and OS-03 (sampled in 1985) are also at elevations lower than groundwater elevations at the Landfill and are at approximate elevations of 220 and 240 feet NGVD 29, respectively (see Figure 3).

Off-site wells were sampled as part of the 5-year review process in July 2020, September 2021, and December 2021. The July 2020 sampling event was performed at six downgradient off-site wells. The September and December 2021 sampling events were performed at a downgradient seep and the upper aquifer well at 13399 Olympic Drive Southeast, which is southwest of the Landfill (Parcel 012201-1-005-2001). The September 2021 OS-01 seep sample was excessively turbid with a measured turbidly of 81.6 NTU and therefore, the analytical results are likely biased high for metals. The December 2021 seep sample had a turbidity of 4.96 NTU, which is acceptably low and yielded representative results. Historical and more recent analytical data for off-site wells and the off-site seep are summarized in Table 4. Off-site well and seep locations including 2020, 2021, and historical data are presented in Table 4 and are summarized below:

- None of the off-site well or seep samples exceeded Washington State Drinking Water Standards for arsenic, iron, or vinyl chloride in data from the 2020 and 2021 sampling events.

- VOCs, including vinyl chloride, were not detected in samples from any of the six off-site wells sampled in 2020 or in the samples from off-site well OW-10 and off-site seep OS-01 sampled in 2021.

- Manganese concentrations from off-site wells OW-3 and OW-4 slightly exceeded the Washington State Drinking Water and Groundwater Secondary Standard of 50 µg/L for manganese in 2020. However, both wells are completed in the deeper confined aquifer, which is hydraulically separated from the upper aquifer beneath the Landfill by a thick layer of low permeability glacial clay. Therefore, these manganese concentrations are not related to conditions at the Landfill.

- Arsenic was not detected at concentrations greater than the Washington State Drinking Water Primary Standard of 10 µg/L in samples from any of the wells or seep sampled.

However, the presence of elevated arsenic in groundwater (relative to more conservative Washington State Groundwater Standards) is a regional issue caused by naturally occurring arsenic in Western Washington geology.

- The greatest arsenic, iron, and manganese concentrations detected in off-site wells are in samples from deeper confined aquifer wells, which are not hydraulically connected to the upper aquifer beneath the Landfill.

The seven downgradient off-site water supply wells and one downgradient seep that were sampled in 2020 and 2021, range in distance from approximately 930 to 1,660 feet to the nearest edge of the solid waste in the Landfill, were found to not be impacted by the Landfill. This empirical demonstration indicates that water-supply wells located greater than approximately 1,000 feet from the downgradient edge of the solid waste were not impacted, and are not expected to be impacted, by dissolved metals associated with the Landfill in the future. The risk of new water supply wells being installed closer than 1,000 feet from the Landfill is eliminated by the prohibition against installation of water supply wells within 1,000 feet of the Landfill boundary in accordance with WAC 173-160-171.

Manganese concentrations measured in samples from downgradient monitoring wells at the Landfill, particularly MW-3, MW-8, and MW-10, were identified by Ecology as a potential concern for off-site wells. However, manganese concentrations in samples from these wells have a downward trend over the most recent 5 years of data, which is the time interval for which statistical trends are evaluated in quarterly and annual groundwater monitoring reports for the Landfill. Manganese time-series plots with trendlines for the most recent 5 years of data are presented in Attachment D. These data trends indicate improving groundwater conditions for manganese in samples from downgradient Landfill monitoring wells.

6.0 NEW INFORMATION AND LAWS

6.1 New Scientific Information on Hazardous Substances

Regulations and standards evaluated as Applicable or Relevant and Appropriate Requirements (ARARs) in the CAP for the development of the site-specific groundwater CULs for the Landfill were reviewed to identify changes or updates to the standards and criteria that might have occurred since the CAP was approved in 2015. The specific regulations and standards that were reviewed for changes to numerical CULs, standards, or criteria since are listed below:

- Water Quality Standards for Groundwaters of the State of Washington (WAC 173-200-040)
- Washington State Drinking Water Standards (WAC 246-290-310)
- MTCA (WAC 173-340-720)
- MTCA Method B CLARC Database Levels
- Safe Drinking Water Act, Primary Drinking Water Regulations (40 Code of Federal Regulations [CFR] 141)

The review identified one change that is potentially relevant to the Landfill.

- In May 2019 the oral reference dose of 0.14 milligrams per kilogram per day (mg/kg-day) for manganese now includes manganese from all sources, including diet. The use of a modifying factor of 3 was applied to the oral reference dose for non-diet related exposures as recommended by EPA's Integrated Risk Information System (IRIS). The oral reference dose has been divided by 3 resulting in a new value of 0.0467 mg/kg-day to be applied to non-food source such as soil and water. As a result, the updated MTCA Method B CUL for manganese in groundwater is 750 µg/L (Ecology 2020).

The MTCA Method B regulatory level change for manganese could materially impact the remedial actions being implemented under the approved CAP at the Landfill. To address this concern, some of the potentially applicable active remedial actions previously evaluated in the Olalla Landfill RI/FS are re-evaluated in the context of current conditions in Section 8.0.

6.2 New Applicable State and Federal Laws

Post-closure monitoring and reporting at the Landfill is being conducted per WAC 173-304-407 MFS "General Closure and Post Closure Requirements," Kitsap County Board of Health Ordinance 2010-01 "Solid Waste Regulations," and Solid Waste Handling Permits issued by KPHD. Therefore, MTCA and Solid Waste Regulations were reviewed for changes in applicable regulations that might have occurred since the CAP was approved in 2015 that could affect the cleanup actions being performed at the Landfill.

KPHD issued a Solid Waste Landfill Post Closure Permit to the Landfill dated February 18, 2016, per the provisions of WAC 173-304 and Kitsap County Board of Health Ordinance 2010-01. This permit was applicable from January 1, 2016, through December 31, 2020. The specific conditions noted in the Permit state that post-closure activities must be conducted in a manner consistent with MTCA requirements. Specific groundwater, surface water, and Landfill gas monitoring methods and procedures that are performed under the requirements of MFS, the SWHP, and the CAP are documented in a CMP (EPI 2015). The CMP integrates the previously noted monitoring program requirements into one document that contains a site-specific SAP, Quality Assurance Project Plan (QAPP), and HASP. No changes in permit conditions or requirements were noted during the review of the KPHD Permit and specific monitoring requirements are consistent with the CMP.

7.0 CURRENT AND PROJECTED SITE AND RESOURCE USE

This section describes the current and projected future use of the Landfill property and resources that are present within the property.

7.1 Site Use

The 45-acre Landfill property consists of two closed waste cells designated the Phase I and Phase II Areas surrounded by a gravel perimeter road. The Phase I Area is approximately 6.5 acres and contains mixed municipal waste and a small volume of septage sludge capped by a 2-foot-thick bentonite amended soil cap with a tested permeability of 1×10^{-6} cm/sec or lower. The Phase II Area is approximately

4.5 acres and contains demolition and construction waste capped by a vegetated soil cap. These waste disposal areas will continue to be managed under MFS Post Closure Care (WAC 173-304) and Kitsap County Board of Health (KCBH) Ordinance 2010-01.

The property will remain a closed sanitary landfill subject to post-closure care for the foreseeable future. Post-closure care may be terminated when site-specific groundwater CULs have been met at the CPOC and the other post-closure criteria have been achieved. KCPW intends to prepare and file an Environmental Covenant, Land Use Control Implementation Plan, and Notice of Conveyance or Other Transfer of an Interested Party upon property transfer. An Environmental Covenant would also be prepared and filed when the cleanup action is complete or when the facility no longer operates under a post-closure permit.

Surrounding properties outside of the Landfill would not be subject to any of the land use restrictions associated with the environmental covenant. However, there is a prohibition against installation of water supply wells within 1,000 feet of the Landfill boundary in accordance with WAC 173-160-171.

7.1.1 Permit Requirements

The Permit issued by KPHD in 2016 (KPHD 2016) is the main document containing permit requirements with regards to use of the property that must be met by KCPW. The Permit specifies that because the Site is undergoing a MTCA cleanup action it is subject to the Olalla Landfill Cleanup Action Plan (Parametrix 2014b) and the CMP (EPI 2015).

The Permit specifies that KCPW shall provide post closure activities to allow for continued facility maintenance and monitoring of air, land, groundwater, and surface water as long as necessary for the facility to stabilize, to protect human health and the environment as determined by KPHD. The post-closure activities shall be conducted in strict compliance with WAC 173-304, KCBH Ordinance 2010-1, and the conditions of the Permit.

The Permit states that KCPW shall perform post-closure activities including, but not limited to: groundwater monitoring; surface water monitoring; landfill gas monitoring; and proper operation and maintenance of the facility, facility structures, and facility monitoring systems for their intended use for a period of no less than 20 years from the date of final closure (May 1989). The Permit further states that KCPW shall provide all activities necessary to allow for continued facility maintenance, including but not limited to:

- stormwater quantity and quality control
- slope stability, erosion, and dust control
- maintenance of access roads and ditches
- maintenance of facility structures and systems
- control and minimization or elimination of threats to human health and the environment
- control of unauthorized entry by lockable gates, barriers, fences, etc. at the property boundary

7.1.2 Land Use Restrictions

Land use restrictions are currently in place in the form or requirements established in the Permit and Kitsap County Board of Health Solid Waste Ordinance 2010-01. These controls and restrictions will continue until CULs and other post-closure criteria are achieved. Controls include fencing, locked gates, and signage to limit and restrict access to the Landfill.

The Landfill is restricted from land uses that might interfere with implementation of the CAP or ongoing monitoring and maintenance of the landfill cap, stormwater system, and landfill gas flares. Perimeter fencing and locked gated entrances enforce access limitations. KCPW inspects the gates, fences, locks, no trespassing signs and repairs or replaces these access restriction structures and devices as needed to maintain their integrity. In addition, surface disturbances and activities that might result in the release or exposure to the environment of the waste contained in the Landfill cells are prohibited within the capped area of the Landfill.

7.1.3 Groundwater Use Restrictions

There are no current restrictions in place in the existing downgradient domestic water supply wells. Groundwater in the upper aquifer beneath the landfill appears to be used for domestic drinking water supply for wells completed in the upper aquifer as denoted by black location markers on Figure 3. However, most of the domestic water supply wells identified downgradient of the Landfill are completed in the deeper aquifer and are separated from the upper aquifer by the low permeability Lawton Clay Formation.

7.2 Resource Use

No uses of any resources have occurred at the Landfill in the past or are anticipated to occur in the future.

8.0 AVAILABILITY AND PRACTICABILITY OF ALTERNATIVE REMEDIES

MNA with land use controls and ongoing monitoring are the appropriate response action for the Landfill. These remedial actions are consistent and appropriate for site-specific conditions at the landfill per WAC 173-340-370(7). However, the recent regulatory change to a lower MTCA Method B CUL for manganese at a concentration of 750 µg/L, and the recently increasing dissolved manganese concentration trend in data from downgradient well MW-3 warrant additional evaluation of potential cleanup action alternatives from the RI/FS in the context of current groundwater conditions. The cleanup action alternatives considered for re-evaluation are presented below:

1. **Monitored Natural Attenuation and Land Use Controls**. This alternative is a continuation of the cleanup actions currently being conducted at the Landfill and includes groundwater and flare monitoring and post closure maintenance and repair. The elements of this alternative will continue to be implemented regardless of any selected additional remedial action.

2. **Low Permeability Cap (two options)**

    a. Low permeability bentonite amended soil cap for the Phase II Area of the Landfill.

    b. Low permeability geomembrane cap for both the Phase I and Phase II Areas of the Landfill.

3. ***In-Situ* Physical/Chemical Treatment: Air Sparging and Complexation**

These potentially applicable cleanup action alternatives are further discussed and evaluated in the following sections.

8.1 Alternative 1 MNA and Land Use Controls

This alternative is currently being implemented at the Landfill and consists of:

- MNA for groundwater and landfill gas system monitoring; and
- continued application of Land Use Controls to reduce the potential for exposure to contaminated groundwater.

8.1.1 Description of Alternative 1, MNA, and Land Use Controls

MNA consists of continuing the post closure monitoring and maintenance activities as specified in the Landfill Final Closure Plan and the SWHP. Current activities include the following:

- Continued quarterly monitoring of five groundwater monitoring wells. Annual monitoring of two crossgradient groundwater monitoring wells (MW-5A and MW-7) and one surface water location and quarterly and annual reporting per the SWHP.
- Continued inspection, maintenance, and repair of Landfill closure systems, including the cap, drainage ditches, and the Landfill gas system.
- Continued quarterly monitoring, maintenance, and operation of the Landfill gas system.

8.1.1.1 Groundwater MNA

Groundwater MNA relies upon natural attenuation processes (within the context of controlled and monitored site conditions) to achieve the Cleanup Action Objectives. Natural attenuation is the process by which concentrations of chemicals introduced into the environment are reduced over time by natural physical, biological, and chemical processes. Natural attenuation has been shown to effectively reduce the concentrations of inorganic and organic contaminants in groundwater.

WAC 173-340-370(7) identifies that MNA might be an appropriate remediation strategy at sites that have the following characteristics:

Characteristic	Conditions at Olalla Landfill
Source control, including removal and/or treatment of hazardous substances, has been conducted to the maximum extent practicable.	The Landfill Phase I Area was closed with a low permeability bentonite-amended soil cap in accordance with Chapter 173-304 WAC. The cap is monitored and maintained in accordance with the Landfill closure plan and the SWHP. The Phase II Area does not have an engineered low permeability cap; however, the Phase II Area is covered by a minimum of 1 foot of soil and construction debris wastes in this area remain dry and are separated from the uppermost aquifer by 40 to 50 feet, indicating no contact between waste and groundwater.
Leaving contaminants on site during the restoration time frame does not pose an unacceptable threat to human health or the environment.	Groundwater at the Landfill exceeds CULs at the CPOC; however, no direct contact exposure route for groundwater ingestion or contact is identified. Continued post-closure operation, periodic off-site water supply well sampling and land use controls will reduce the potential for future changes to groundwater exposure scenarios.
There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.	Based on typical trends observed with other similar closed Chapter 173-304 WAC landfills, declining leachate releases and landfill gas production over time lead to long-term declining trends in groundwater contaminant concentrations. Except for manganese in samples from MW-3, groundwater concentrations of COCs at the Landfill have been steady or declining during the most recent 5-year monitoring period and would be expected to continue to decline and ultimately achieve CULs.
Appropriate monitoring requirements are conducted to evaluate if conditions favorable for natural attenuation processes are maintained and that human health and the environment are protected.	Quarterly groundwater monitoring is required at the Landfill as part of the SWHP and will continue in accordance with the SWHP. Monitored parameters include parameters used to evaluate if natural attenuation processes are taking place including specific conductance, pH, DO, and ORP. Land use restrictions currently in place and permit limitations on developing new water supply wells on adjacent properties within 1,000 feet of the Landfill will continue to protect potential exposure through direct contact or ingestion of groundwater that exceeds CULs.

Natural attenuation processes at the Landfill that may reduce the COC concentrations in groundwater during transport downgradient are dispersion, dilution, chemical stabilization, and sorption. Dispersion and dilution appear to be the current dominant attenuation processes at the Landfill; however, as the leachate generation and anaerobic conditions beneath the Landfill dissipate over time, the geochemistry within the subsurface will change and chemical stabilization and sorption will become the dominant attenuation processes. Supporting information for this statement includes the following:

- pH is neutral to slightly acidic in samples collected from all Landfill wells, which allows for the mobilization of metals in reducing conditions or the precipitation or re-adsorption of metals to the aquifer matrix in oxidizing conditions.

- DO occurs at low levels in samples collected from downgradient Landfill wells. Downgradient wells demonstrate elevated concentrations of one or more metal COCs, which demonstrates anaerobic (reducing) geochemical conditions are occurring. Upgradient and crossgradient Landfill wells show elevated dissolved oxygen levels where metals concentrations are low.

- ORP level is high (greater than 100 millivolts [mV]) in samples collected from Landfill wells where metals concentrations are low indicating oxidizing conditions and the ability to reduce metals concentrations where oxidizing conditions exist. ORP levels are increasing in all Landfill wells as noted in the ORP time series graph (Attachment F).

8.1.1.2 Groundwater Monitoring

MNA requires a robust groundwater monitoring program to ensure the Cleanup Action Objectives are being achieved in a reasonable time frame. The long-term groundwater monitoring program for the Landfill consists of specific wells, specific constituents, and monitoring frequency to ensure achievement of the Cleanup Action Objectives and support the post-closure care requirements.

Depth-to-water measurements are measured at all on-site monitoring wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-5A, MW-6, MW-7, MW-8, and MW-10. These wells were selected because they provide appropriate upgradient, crossgradient, and downgradient coverage of groundwater elevations at the Landfill. Downgradient monitoring wells MW-3, MW-6, MW-7, MW-8, and MW-10, also represent monitoring locations for the CPOC. KCPW has also elected to measure depth to water at well MW-5 to track changes in the water level of the shallow perched groundwater north of the Landfill.

The constituents that are analyzed are VOCs (including vinyl chloride by selective ion monitoring [SIM]), dissolved metals (including iron, manganese, and arsenic), conventional constituents (e.g., ammonia, chloride, total organic carbon, bicarbonate, carbonate, nitrate, nitrite, sulfate, alkalinity), and total coliform. Groundwater monitoring includes field parameter measurements during purging (i.e., pH, specific conductance, DO, temperature, and ORP). Field parameter data provide an indication of the aquifer's geochemical characteristics. The dissolved metals analysis combined with field data can demonstrate whether reducing geochemical conditions are present and are mobilizing metals that are more soluble in anaerobic (reducing) geochemical conditions. Other constituents might be included in the monitoring program as required by the SWHP.

Groundwater monitoring has been implemented in a manner designed to meet the requirements specified in the SWHP. The County is performing a technical analysis to demonstrating the effectiveness of semi-annual sampling using the most recent 5 years of quarterly data from the current monitoring well network, including new wells MW-8 and MW-10. Adjustments to the monitoring frequency should occur based on data evaluations presented in a separate technical memorandum (to be submitted under separate cover).

The groundwater monitoring program discussed herein is based on the current SWHP and is assumed to continue in accordance with the current SWHP. Implementation of quarterly groundwater monitoring is assumed for cost estimating purposes for a duration of 30 years; however, KCPW anticipates groundwater monitoring frequency, constituents, and duration will be modified and reduced in coordination with KPHD.

8.1.1.3 Land Use Controls

Land Use Controls are currently in place in the form of requirements established in the SWHP and Kitsap County Board of Health Solid Waste Ordinance 2010-01. These controls will continue until CULs are achieved and other Landfill post-closure criteria are achieved. Controls include fencing and signage to limit access to the Landfill. The Landfill property is also listed in County and State records as a landfill and water well installation and new water supply wells are restricted within 1,000 feet of the property boundary. The Landfill is regulated under Washington State Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC). Existing deed restrictions for the Landfill property are in place and will be maintained.

8.1.2 Alternative 1 Cost Estimate

Alternative 1 includes routine inspections and maintenance of the closure system and environmental monitoring as specified in the 2022 SWHP and the Post Closure Maintenance Plan. The post-closure program will be in accordance with the SWHP; however, for estimating purposes the following costs are included in the estimate:

- Inspection of final cap to identify settlement and erosion effects and correct deficiencies
- Inspection, clearing, cleaning, and repair of drainage ditches
- Inspection and regrading of access roads
- Inspection and repair of groundwater monitoring wells and dedicated sampling devices
- Landfill gas monitoring and flare operation and maintenance
- Quarterly monitoring of groundwater for:
  - Dissolved metals (iron, arsenic, manganese, zinc, barium)
  - Total metals (sodium, calcium, potassium)
  - Total coliform
  - Conventionals (carbonate, bicarbonate, chloride, sulfate, nitrate, nitrite – nitrogen, ammonium nitrogen)
  - Chemical oxygen demand (COD)
  - Total organic carbon (TOC)
  - VOCs by EPA Method 8260C
  - Vinyl chloride by SIM

  - o Field Parameters (temperature, pH, oxidation-reduction potential, dissolved oxygen, and specific conductance)
  - o Field measurements – depth to water

- Quarterly and annual reporting of Landfill monitoring and maintenance activities. The groundwater monitoring program will be in accordance with the SWHP; however, for estimating purposes, a 30-year monitoring period was assumed.

- Annual Solid Waste Handling Permit fees.

Based on the items above, the total estimated net present value for Alternative 1 is $2,824,181. Attachment H contains a detailed breakdown of the estimated costs associated with Alternative 1.

8.2 Alternatives 2a and 2b, Low Permeability Cap with MNA and Land Use Controls

Implementation of this alternative would consist of the following:

- Installation of a Low Permeability Cap over portions of the Landfill.
- MNA of groundwater.
- Continued application of Land Use Controls to reduce the potential for exposure to contaminated groundwater.

Because there is a range of low permeability cap configurations that may best achieve the goals for the cleanup action, this alternative is further subdivided into Alternative 2a and 2b, as follows:

- Alternative 2a would consist of a low permeability soil cap for the Phase II Area of the Landfill.
- Alternative 2b would consist of a geomembrane cap system over the entire Phase I and Phase II Areas.

Both Alternative 2a and 2b would include MNA of groundwater and Land Use Controls.

8.2.1 Description of Alternative 2a Low Permeability Soil Cap

Alternative 2a includes installation of a low permeability bentonite amended soil cap over the Phase II Area. The low permeability soil cap for the Phase II Area will consist of an engineered soil cap consistent with the low permeability cap installed on the Phase I Area of the Landfill. The cap will be constructed of a minimum 24-inch low permeability (1 x 10^{-6} cm/sec hydraulic conductivity) bentonite amended soil layer emplaced and compacted on top of the existing Landfill surface, and an 18-inch side slope layer overlaid with an 8-inch rock armor layer for the side slope areas. The surface will be graded to 3 percent slopes directed toward engineered drainage ditches to promote surface water runoff, covered with topsoil, and planted with native grasses to promote evapotranspiration. All road access will consist of embankment material and crushed rock surfacing.

8.2.1.1 Groundwater Monitoring

The current groundwater monitoring program would continue unchanged under Alternative 2a.

8.2.1.2 Land Use Controls

Land Use Controls would be like current conditions except the Phase II Area would be covered with a low permeability bentonite-amended soil cap, which would require ongoing monitoring and maintenance consistent with the Phase I Area cap.

8.2.1.3 Alternative 2a Cost Estimate

The cost for Alternative 2a would be the same as current conditions (MNA plus land use controls) plus the addition of a low-permeability bentonite-amended soil cap. This additional cost element would involve the following:

- Design and construction of a low permeable soil cap over the 4.5-acre Phase II Area.

- Monitoring and routine maintenance of the low permeable bentonite amended soil cap. Monitoring would occur quarterly concurrent with the environmental monitoring. TRC assumes that maintenance improvements would be required every 5 years. Monitoring and maintenance will occur in accordance with the SWHP; however, for cost estimating purposes a 30-year monitoring and maintenance period is assumed.

Based on the items above, the total estimated net present value for Alternative 2a is $4,199,114. Attachment H contains a detailed breakdown of the estimated costs associated with Alternative 2a.

8.2.2 Description of Alternative 2b Low Permeability Geomembrane Cap

For this cleanup action alternative, the low permeability soil cap is replaced with a geomembrane cap over both Phase I and Phase II Areas. The low permeability cap for the Landfill will consist of an engineered geomembrane cap. Generally, this requires excavation/embankment, grading and compacting subgrade, construction of a landfill cap system, road construction and grading, and stormwater perimeter ditch. Although the Landfill was closed in accordance with Chapter 173-304 WAC, the low permeability geomembrane cap would be constructed using Chapter 173-351 WAC Criteria for Municipal Solid Waste Landfills as a guide. The top liner consists of a compacted bedding layer and an overlying 30 mil PVC geomembrane. The cap system consists of a 24-inch soil layer on top of the Landfill, and an 18-inch side slope layer overlaid with an 8-inch rock armor layer for the side slope areas. All road access will consist of embankment material and crushed surfacing. The installation of a geomembrane would require reconstruction of the passive Landfill gas system.

8.2.2.1 Groundwater Monitoring

The current groundwater monitoring program would continue unchanged under Alternative 2b.

8.2.2.2 Land Use Controls

Land Use Controls would be similar except the entire Landfill would be covered with a low permeability geomembrane cap system, which would require ongoing monitoring and maintenance.

8.2.2.3 Alternative 2b Cost Estimate

The cost for Alternative 2b would be the same as current conditions plus the addition of a low-permeability geomembrane cap. This additional cost element would involve the following:

- Design and construction of a low permeable geomembrane cap over the 11 acres encompassed by the Phase I and Phase II Areas. The design and construction would be more complex and costly because of the use of a geomembrane layer and the larger area to be covered.

- Monitoring and routine maintenance of the low permeable geomembrane cap system. Monitoring would occur quarterly concurrent with the environmental monitoring in accordance with the SWHP. TRC assumes that maintenance improvements would be required every 5 years. Monitoring and maintenance would be conducted in accordance with the SWHP; however, for estimating purposes a 30-year monitoring and maintenance period is assumed. Maintenance requirements would be greater than Alternative 2a because of the use of a geomembrane.

- Reconstruction of the existing Landfill passive gas recovery system.

Based on the items above, the total estimated net present value for Alternative 2b is $6,681,658. Attachment H contains a detailed breakdown of the estimated costs associated with Alternative 2b.

8.3 Alternative 3 *In-Situ* Physical/Chemical Treatment: Air Sparging and Complexation

Alternative 3 would consist of the following:

- Air sparging to remediate iron and manganese in groundwater.
- Complexation to remediate arsenic in groundwater.
- Low permeability soil cap for the Phase II Area.
- Additional groundwater monitoring

8.3.1 Description of Alternative 3

All the requirements for Alternative 2a would apply to Alternative 3, including a low permeability bentonite-amended soil cap on the Phase II Area of the Landfill, MNA of groundwater, and Land Use Controls. Alternative 3 also includes an air sparging system to add oxygen to the subsurface to create an aerobic (geochemically oxidizing) subsurface environment at the CPOC and a remediation substrate injection system to provide remediation products designed for metals complexation.

8.3.1.1 Air Sparging

Alternative 3 would install an air sparging system consisting of up to 10 air injection wells installed in intervals of approximately 50 feet along the western boundary of the Landfill property, hydraulically upgradient from MW-3, MW-6, MW-8, and MW-10. The air sparging wells would be constructed using a hollow-stem auger drill and extend to approximately 225 National Geodetic Vertical Datum 1929 (NGVD 29) or between 40 and 50 feet bgs depending on location specific hydrogeologic conditions. Wells would be designed with 5 feet of machine-slotted well screen set in a sand filter pack at the base to allow for air injection to increase dissolved oxygen concentrations in groundwater. The air injection wells would be connected to a piping manifold at the surface that would allow compressed air to be distributed as needed between the wells.

The air sparging system would be operated for approximately 25-day intervals (monthly), followed by 5-day shutdown periods to allow for aquifer stabilization, which is necessary for static water level measurements and groundwater sampling to occur. The 5-day shutdown would also to allow for maintenance to the blower, wells, and ancillary equipment. After sampling, the sparging wells would be treated to control iron-fixing bacteria that are common in oxidized environments. The air sparging system would be operated in cycles of approximately 25 days on with 5 days off for the first year as described above. After the first year of operation the air sparging system would be operated for approximately 3-month intervals (quarterly) followed by 5-day shutdown periods to allow for aquifer stabilization, water level measurements, groundwater sampling, and maintenance. For this evaluation, the air sparging system is assumed to operate for 30 years. The operating duration is an estimate based on professional judgment and because refuse (source area) will be left in place with no source removal or other active remediation. The air sparge system is intended as a barrier system that will be necessary until the source area degrades to an extent that geochemical conditions created by decaying carbon sources in the source area will not elevate downgradient COC concentrations.

Prior to final design of the full-scale system, a single well pilot test would be conducted to refine the full-scale treatment approach for air sparging. The pilot test would help refine the air flow requirements and range of influence of each air injection point. The pilot test would involve the installation of one air injection well. Air would be injected into the well for a 30-day period and dissolved oxygen would be monitored daily in the adjacent monitoring wells.

8.3.1.2 Complexation

Alternative 3 also includes installation of up to 21 injection points installed in intervals of approximately 25 feet along the western edge (downgradient edge) of the west perimeter road of the Landfill. The injection points would extend approximately 60 to 70 feet bgs and extend approximately 20 feet below the seasonal low groundwater level. The bottom of the injection points would be fitted with 20 feet of slotted well screen set in a sand filter pack that would allow for the injection of a remediation product known as Metals Remediation Compound (MRC™). MRC™ would be injected at a rate of approximately 100 pounds per injection point. TRC assumes that a total of five annual treatments would be necessary to decrease groundwater metals concentrations to less than regulatory levels. After 5 years of MRC™ treatment the air sparging treatment alone is estimated to be sufficient to maintain metals at concentrations less than regulatory levels. Metals concentrations would be measured during ongoing MFS groundwater sampling at downgradient monitoring wells MW-3, MW-6, MW-8, and MW-10.

Bench-scale treatability and pilot tests would be conducted to help refine the full-scale treatment approach for Alternative 3. Results of the treatability and pilot tests would be used to refine the full-scale treatment approach for groundwater.

In addition to the air sparging and MRC™ injection points Alternative 3 would include installation of an approximately 20-foot by 20-foot maintenance building to house a pad-mounted compressor and provide for chemical handling and storage, and for maintenance of remediation equipment and supplies.

8.3.1.3 Additional Groundwater Monitoring

Groundwater monitoring, in addition to the requirements presented in Alternative 1, would involve monthly performance sampling of air sparging wells during the first year, followed by quarterly performance sampling until levels of iron and manganese were reduced to concentrations less than CULs. The air injection wells would also be sampled for arsenic to assess the effectiveness of complexation efforts. However, ongoing MFS groundwater monitoring is sufficient to evaluate and demonstrate permanence of remediation efforts.

8.3.1.4 Alternative 3 Cost Estimate

The cost for Alternative 3 includes the following elements:

- Plan, conduct, and report on a pilot test to refine full scale treatment approaches.
- Installation of an air sparging system including the construction of up to 10, 2-inch diameter air injection wells to an average depth of 45 feet bgs. The air sparging system would also include the procurement and installation of an air compressor and associated piping, instrumentation, and power.
- Construction of a 20-foot by 20-foot building.
- Plan, conduct, and report of bench-scale treatability testing of MRC™ technology.
- Installation of the MRC™ injection network including the construction of up to 21, 2-inch diameter injection points to an approximate depth of 65 feet bgs. This would involve contracting construction services, site improvements to facilitate construction, drilling and well materials, and oversight and reporting.
- Purchase and delivery of the MRC™ chemicals.
- Five rounds of annual MRC™ chemical injection.
- 48 rounds of additional groundwater monitoring of 10 air sparge wells,
- Decommissioning of the remediation systems, including decommissioning of the injection points and site restoration

- Annual and close out reporting.

Based on the items above, the total estimated net present value for Alternative 3 is $7,131,074. Attachment H contains a detailed breakdown of the estimated costs associated with Alternative 3.

Direct active treatment of solid wastes in municipal solid waste (MSW) landfills is impracticable because of the volume and heterogeneity of the waste material contained in MSW landfills (EPA 1993a and 1993b). Therefore, more permanent remedial alternatives involving active treatment are not practical for MSW landfills, including the Olalla Landfill.

9.0 IMPROVED ANALYTICAL METHODS

Analytical methods used at the time of implementation of the Landfill remedial action were capable and remain capable of detection of constituents at concentrations less than or equal to the approved site-specific CULs and are consistent with laboratory methods cited in the Permit. Therefore, the potential presence of improved analytical methods is not anticipated to be a factor or consideration for future decisions or recommendations proposed for the Landfill.

10.0 PROPOSED ACTIONS FOR 2021 TO 2025

This section provides recommendations for improving the efficiency and effectiveness of the selected remedial action consisting of MNA, groundwater monitoring, and institutional controls as described in the CAP (Parametrix 2014b). As described in earlier sections of this report, the selected remedial action includes the previously completed presumptive remedies for closure of MSW landfills, including installation and maintenance of a low permeability cap, landfill gas controls, and stormwater management. These actions have resulted in significant improvement to groundwater quality at the Landfill as demonstrated by time-series plots for site-specific COCs presented in Attachment C.

Best fit trend lines for all COCs exhibit decreasing concentration trends in all four downgradient wells (i.e., MW-3, MW-6, MW-8, and MW-10) with two exceptions: arsenic concentrations in data from MW-10 and manganese concentrations in data from MW-3. However, manganese concentration trendlines in samples from all downgradient Landfill monitoring wells are now downward based on the most recent 5 years of data (see Attachment D).

As a result of the positive outcomes documented in this RASR, continued implementation and maintenance of the existing engineering controls is recommended. The significant improvements in groundwater quality and the extensive historical record of groundwater monitoring data indicate that modifications to optimize the groundwater monitoring program as defined in the CAP and SAP should be recommended for consideration.

11.0 REFERENCES

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Tables

Table 1
January 2022 Bar Hole Survey Field Data
Remedial Action Status Report
Olalla Landfill
Kitsap County, Washington

Bar Hole Number	Time	Methane (% volume)	% LEL	Oxygen (% volume)	Carbon Dioxide (% volume)	Temperature (°C)
PR-1	8:54	0.0	0	20.7	0.1	11
PR-2	9:06	0.0	0	20.7	0.1	11
PR-3	9:14	0.0	0	20.7	0.2	11
PR-4	9:20	0.0	0	19.5	0.8	11
PR-5	9:28	0.0	0	20.5	0.6	10
PR-6	9:46	0.0	0	17.5	1.7	10
PR-7	9:55	0.0	0	20.5	0.4	10
PR-8	10:09	0.0	0	21.0	0.1	10
PR-9	10:25	0.0	0	20.9	0.1	10
PR-10	10:41	0.0	0	20.8	0.1	10
PR-11	10:54	0.0	0	21.1	0.1	10
PR-12	11:11	0.0	0	21.1	0.0	10
PR-13	11:19	0.0	0	21.2	0.0	10
PR-14	11:44	0.0	0	21.2	0.0	10
PR-15	11:54	0.0	0	21.0	0.0	10
PR-16	12:00	0.0	0	20.9	0.1	10
PR-17	12:07	0.0	0	21.2	0.0	10
PR-18	12:13	0.0	0	20.8	0.1	10
PR-19	12:57	0.0	0	21.1	0.0	11
PR-20	13:10	0.0	0	21.0	0.0	11
PR-21	13:46	0.0	0	20.9	0.1	11
PR-22	14:00	0.0	0	21.0	0.0	11
PR-23	14:15	0.0	0	21.0	0.1	11
PR-24	14:37	0.0	0	21.3	0.0	11
PR-25	14:41	0.0	0	21.2	0.1	11
PR-26	14:48	0.0	0	21.2	0.0	11
PR-27	14:54	0.0	0	21.4	0.0	11
PR-28	15:02	0.0	0	21.3	0.0	11
PR-29	15:08	0.0	0	21.2	0.1	11
PR-30	15:20	0.0	0	20.8	0.2	11
LF-A-01	9:25	0.0	0	19.0	1.0	6
LF-A-02	9:40	0.0	0	20.6	0.1	6
LF-A-03	9:49	0.0	0	21.0	0.0	6
LF-A-04	9:55	0.0	0	20.7	0.1	6
LF-A-05	10:12	0.0	0	19.2	0.2	6
LF-B-01	10:22	0.0	0	20.5	0.3	6
LF-B-02	10:30	0.0	0	20.9	0.1	6
LF-B-03	11:06	0.0	0	21.1	0.0	6
LF-B-04	11:22	0.0	0	21.1	0.0	6
LF-B-05	11:29	0.0	0	20.7	0.2	6
LF-B-06	11:45	0.0	0	21.2	0.0	6
LF-B-07	11:56	0.0	0	19.6	1.4	7
LF-B-08	12:03	0.0	0	20.7	0.3	7
LF-B-09	12:09	0.0	0	21.0	0.1	7
LF-B-10	12:19	0.0	0	21.0	0.1	7
LF-B-11	12:33	0.0	0	20.9	0.1	7
LF-B-12	12:42	0.0	0	21.1	0.0	7
LF-C-01	13:36	0.0	0	19.6	0.8	8
LF-C-02	13:40	0.0	0	21.0	0.1	8
LF-C-03	13:47	0.0	0	21.1	0.1	8
LF-C-04	13:55	0.0	0	20.9	0.1	8
LF-C-05	13:59	0.0	0	20.4	1.2	8
LF-C-06	14:04	0.0	0	21.1	0.0	8
LF-C-07	14:11	0.0	0	21.1	0.0	8
LF-C-08	14:23	0.0	0	21.0	0.2	8
LF-C-09	14:48	0.0	0	20.8	0.0	8
LF-C-10	14:56	0.0	0	19.9	0.2	8
LF-C-11	15:02	0.0	0	20.6	0.1	8
LF-C-12	15:20	0.0	0	20.5	0.2	8

Notes:
Survey performed on January 20 and 21, 2022 by TRC.
PR Perimeter Road Sample Location.
LF Phase II Area of Olalla Landfill Sample Location.

Table 2
September 2022 95% Confidence Interval Evaluation Results for Olalla Landfill COCs
Remedial Action Status Report
Olalla Landfill
Kitsap County, Washington

Constituent or Parameter	MW-1	MW-3	MW-5A[a]	MW-6	MW-7[a]	MW-8	MW-10	Regulatory Level	Basis for Comparison
Arsenic - Dissolved	0.10 to 0.10	0.11 to 0.12	0.15 to 0.21	0.383 to 1.06	0.29 to 0.37	1.06 to 1.92	1.74 to 1.96	1.29 µg/L	Site-Specific Cleanup Level
Iron - Dissolved	ND	ND	ND	223 to 848	ND	272 to 706	ND to 21	300 µg/L	Secondary GW and DW Standard
Manganese - Dissolved	ND	5,367 to 6,448	ND	520 to 705	ND	2,353 to 2,791	4,159 to 4,658	50 µg/L	Secondary GW and DW Standard
Vinyl Chloride	ND	ND	ND	ND	ND	ND to 0.02	ND	0.29 µg/L	Site-Specific Cleanup Level

Notes:

All results presented in micrograms per liter (µg/L), unless otherwise noted.

95% Confidence Intervals (Cis)are evaluated over the most recent 5 years of quarterly monitoring data.

a Crossgradient wells MW-5A and MW-7 are sampled annually; data are through September 2022.

DW Drinking water.

GW Groundwater.

ND Data all non-detects or four or fewer detections.

(Red) 95% Lower CI Exceeds Regulatory Level (Exceedance).

(Yellow) 95% Upper CI Exceeds Regulatory Level but Lower CI Does Not (No Exceedance, No Compliance).

(Green) 95% Upper CI Does not Exceed Regulatory Level (No Exceedance).

Normally Distributed Data - Parametric Confidence Interval - Data not Transformed.

Non-Normally Distributed Data - Non-Parametric Confidence Interval - Log Base-10 Transformed Data.

Non-Detects treated as 0.

Table 3
September 2022 Mann-Kendall Statistically Significant Trend Test Results for Olalla Landfill COCs
Remedial Action Status Report
Olalla Landfill
Kitsap County, Washington

Constituent or Parameter	MW-1	MW-3	MW-5A[a]	MW-6	MW-7[a]	MW-8	MW-10
Arsenic - Dissolved	**DOWN**	NO TREND	NO TREND	**DOWN**	NO TREND	**DOWN**	**UP**
Iron - Dissolved	NO TREND	NO TREND	NO TREND	**DOWN**	NO TREND	**DOWN**	**DOWN**
Manganese - Dissolved	NO TREND	**DOWN**	NO TREND	**DOWN**	NO TREND	**DOWN**	NO TREND
Vinyl Chloride	NO TREND	NO TREND	NO TREND	**DOWN**	NO TREND	NO TREND	NO TREND

Notes:

a Crossgradient wells MW-5A and MW-7 are sampled annually; data are through September 2022.

Mann-Kendall trends are evaluated over the most recent five years of quarterly monitoring data.

NO TREND = No statistically significant trend.

UP = Statistically significant upward trend.

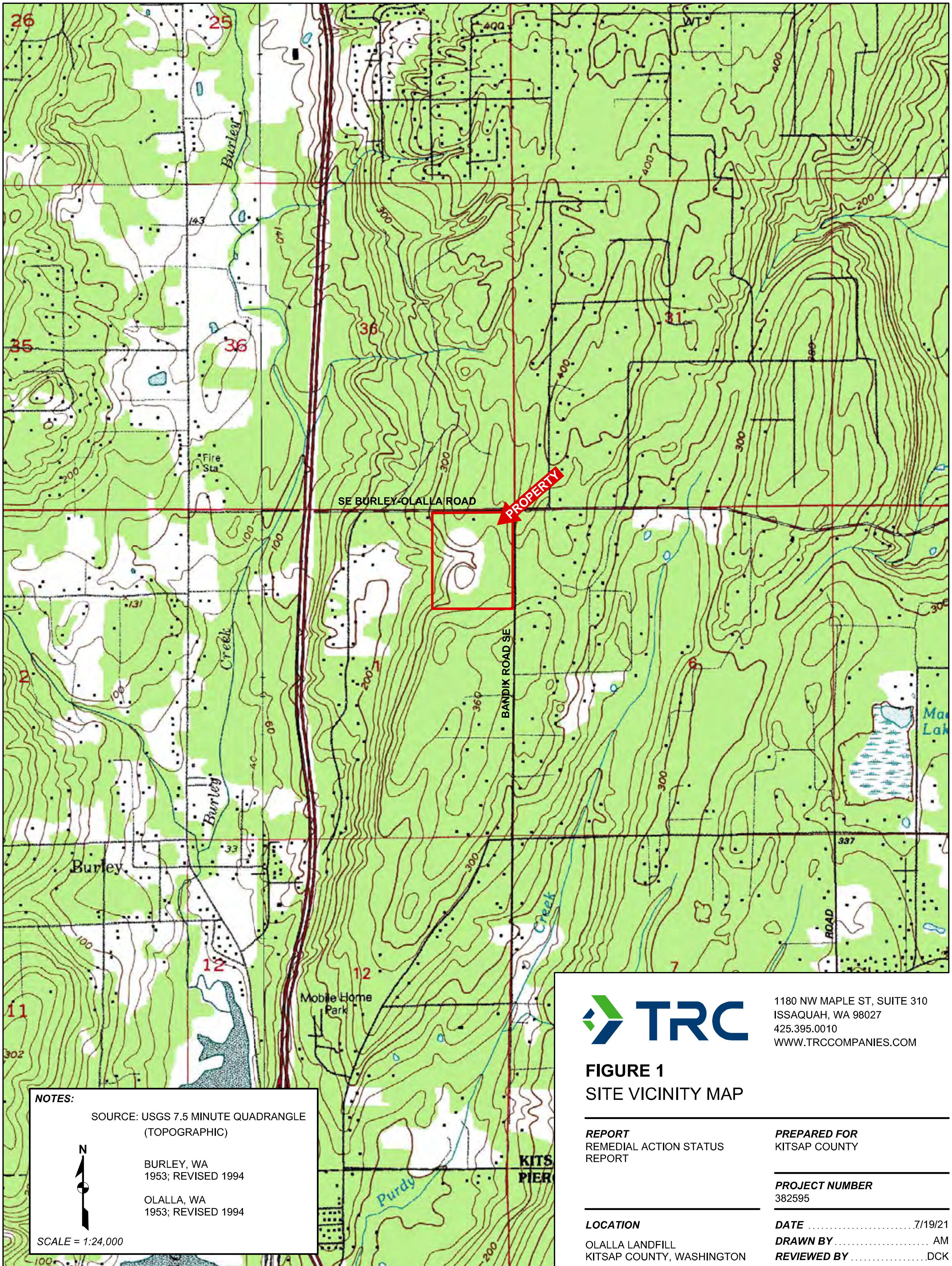
DOWN = Statistically significant downward trend.

Table 4
Historical and Current Off-Site Well and Seep Sampling Data
Remedial Action Status Report
Olalla Landfill
Kitsap County, Washington

Assigned Well ID	Current Well Owner	Street Address	Well Depth (feet)	Date Sampled	Vinyl Chloride	Arsenic	Iron	Manganese
OW-1	South County Transfer Station	Olalla Landfill	159	12/28/2010	<0.02	**0.719**	<20	<5
				7/29/2020	<0.02	**0.84**	<20	**1.2**
OW-2	Leo Pierson	2752 SE Burley-Olalla Rd	107[a]	4/25/1995	<0.01	**0.48**	<10	<2
				9/24/1997	<0.01	**0.16**	<10	<2
				1/27/2011	<0.02	**0.215**	<20	<5
				7/29/2020	<0.02	**0.28**	<20	**6.5**
OW-3	Leo Pierson	2650 SE Burley-Olalla Rd	274	4/25/1995	<0.01	**1.5**	**10**	**37**
				9/24/1997	<0.01	**1.7**	<10	**18**
				1/27/2011	<0.02	**7.04**	**572**	**59**
				7/29/2020	<0.02	**2.36**	**43.2**	**59**
OW-4	Brian Hickman	2590 SE Burley-Olalla Rd	300[a]	4/25/1995	<0.01	**2.77**	**60**	**52**
				9/24/1997	<0.01	**1.8**	**300**	**15**
				12/29/2010	<0.02	**1.68**	**106**	**32**
				7/29/2020	<0.02	**1.95**	**132**	**51.5**
Well #4	Ken Bagwell	13073 Olympic Drive SE	210	4/25/1995	<0.01	**3.56**	**50**	**46**
				9/24/1997	<0.01	**2.4**	**10**	**9**
OW-5	Gene Ryker	13025 Olympic Drive SE	279	1/27/2011	<0.02	**0.535**	**54**	**38**
				7/29/2020	<0.02	**0.798**	<20	**46.4**
OW-9	Cynthia Eriksen	13320 Olympic Drive SE	61	12/29/2010	<0.02	**0.253**	**71**	<5
				7/29/2020	<0.02	**0.37**	<20	**5.2**
OW-10	Patrick Timmons & Karen Aleccia	13399 Olympic Drive SE	45	9/17/2021	<0.02	**0.232**	<36	**1.55**
				12/15/2021	<0.02	**0.245**	<36	<1.6
OS-01			Seep	12/15/2021	<0.02	**0.481**	**104**	**7.1**
G.A. Pierson Well	Sheryl Pierson	13073 Olympic Drive SE	210	8/23/1985	NT	<5	**80**	NT
OS-02			Seep	8/23/1985	NT	NT	**200**	NT
OS-03			Seep	8/23/1985	NT	NT	NT	NT
Washington State Drinking Water Standard					**2[b]**	**10[b]**	**300[c]**	**50[c]**
Model Toxics Control Act Method A or B Groundwater Cleanup Levels					**0.2[d]**	**5[d]**	**11,000[e]**	**750[e]**

Notes:
All results presented in micrograms per liter (µg/L).
Bold Bold result exceeds the laboratory detection limit.
(shaded) Shaded result exceeds the Washington State Drinking Water Standard WAC 246-290-310.
< Result less than laboratory detection limit.
a Well log not available. Total depth reported by homeowner.
b Washington State Drinking Water Primary Standard.
c Washington State Drinking Water Secondary Standard.
d Model Toxics Control Act (MTCA) Method A Groundwater Cleanup Level, Cleanup Levels and Risk Calculations (CLARC) database.
e MTCA Method B Groundwater Cleanup Level, Cleanup Levels and Risk Calculations (CLARC) database.
NT Not tested.

Figures



NOTES:

SOURCE: USGS 7.5 MINUTE QUADRANGLE (TOPOGRAPHIC)

BURLEY, WA
1953; REVISED 1994

OLALLA, WA
1953; REVISED 1994

SCALE = 1:24,000

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FIGURE 1

SITE VICINITY MAP

REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 7/19/21
DRAWN BY .... AM
REVIEWED BY .... DCK

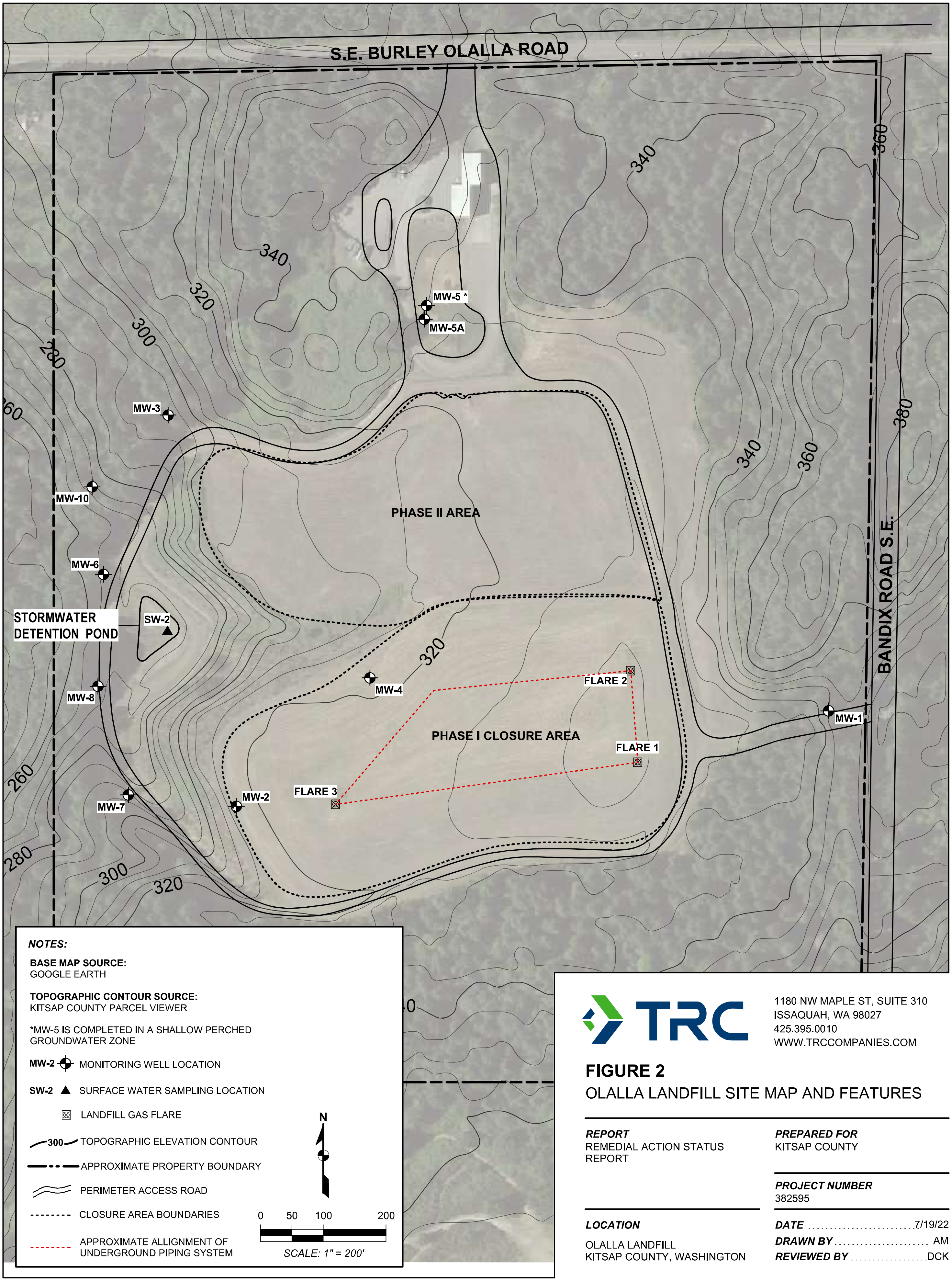

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FIGURE 2

OLALLA LANDFILL SITE MAP AND FEATURES

REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
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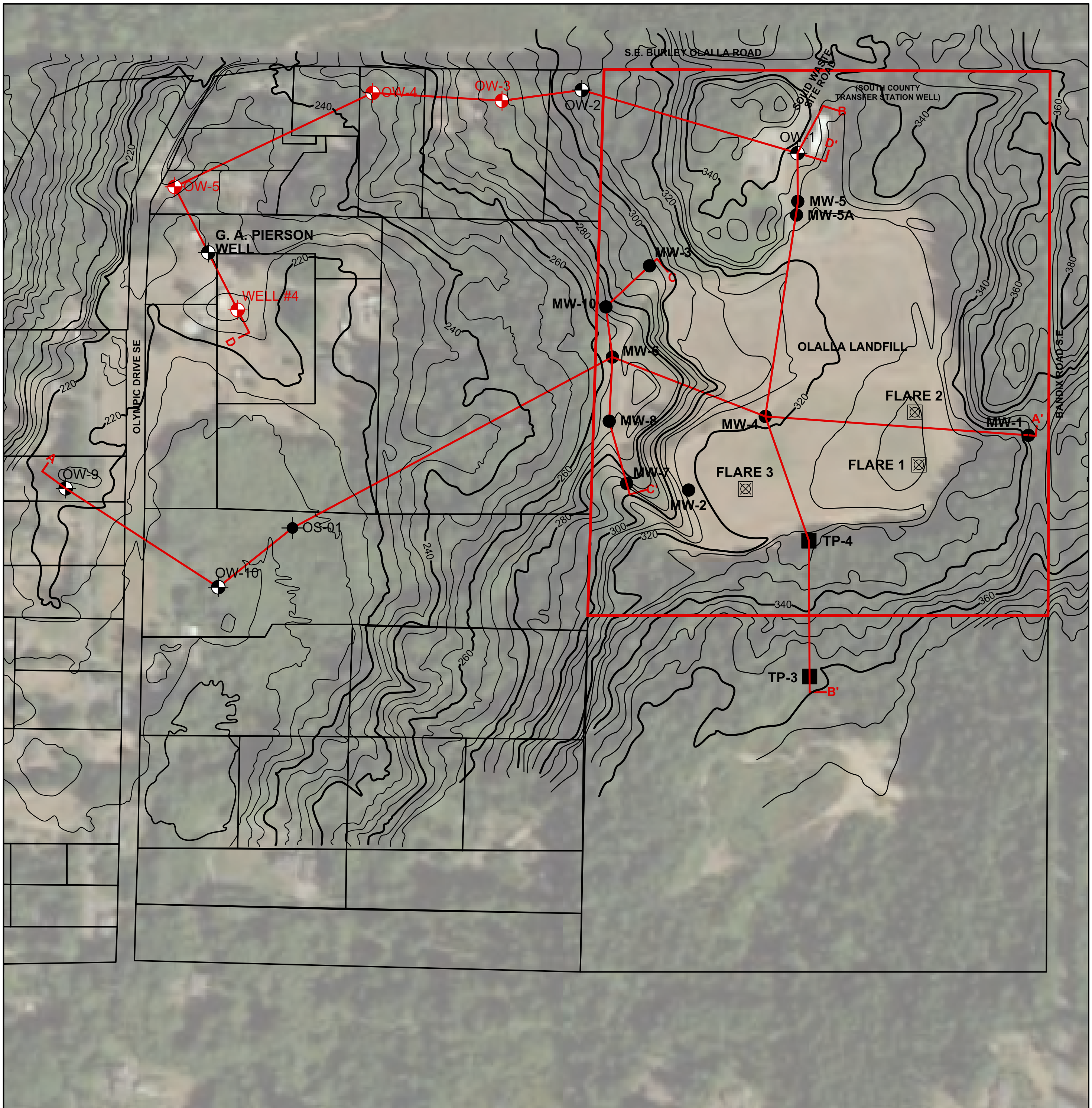
KITSAP COUNTY, WASHINGTON

DATE 7/19/22
DRAWN BY AM
REVIEWED BY DCK



NOTES:

- OFF-SITE WELL LOCATION (UPPER AQUIFER)
- OFF-SITE WELL LOCATION (DEEPER AQUIFER)
- OFF-SITE SEEP LOCATION (UPPER AQUIFER)
- LANDFILL MONITORING WELL
- TEST PIT LOCATION
- FLARE LOCATION
- CROSS-SECTION ALIGNMENT
- APPROXIMATE SUBJECT PARCEL BOUNDARY
- APPROXIMATE SURROUNDING PARCEL BOUNDARY
- TOPOGRAPHIC ELEVATION CONTOURS

AERIAL IMAGERY: GOOGLE EARTH
PARCEL INFORMATION: KITSAP COUNTY (2021)
WELL INFORMATION: ECOLOGY WELL LOG DATABASE (WEBSITE)

N

0 100 200 400

SCALE: 1" = 400'

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FIGURE 3

OFF-SITE WATER SUPPLY WELL AND SEEP SAMPLING LOCATIONS AND HYDROGEOLOGIC CROSS-SECTION ALIGNMENTS

REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 7/19/22
DRAWN BY .... AM
REVIEWED BY .... DCK

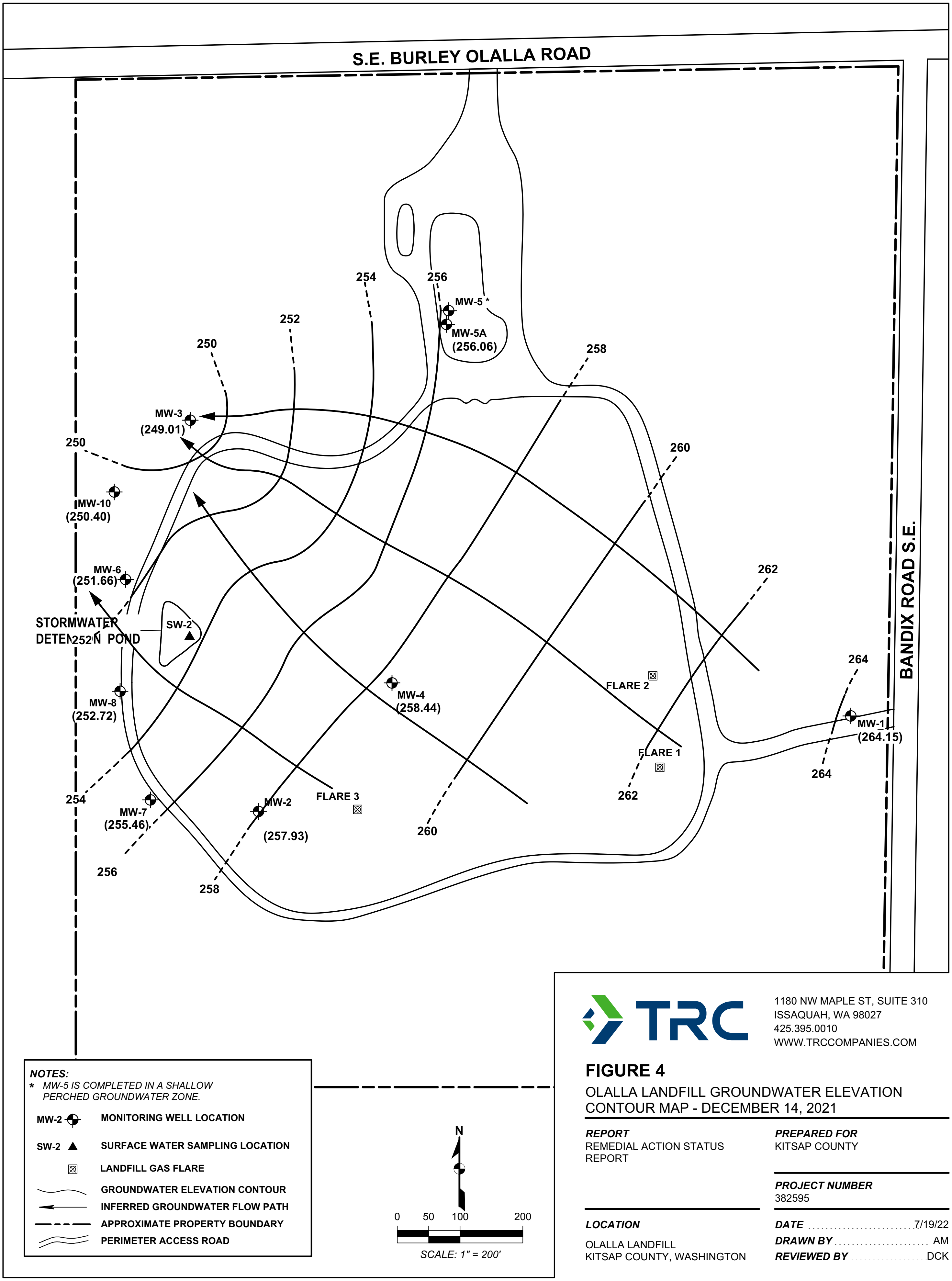

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FIGURE 4

OLALLA LANDFILL GROUNDWATER ELEVATION CONTOUR MAP - DECEMBER 14, 2021

REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 7/19/22
DRAWN BY .... AM
REVIEWED BY .... DCK

OLALLA LANDFILL FLARE METHANE MEASUREMENTS

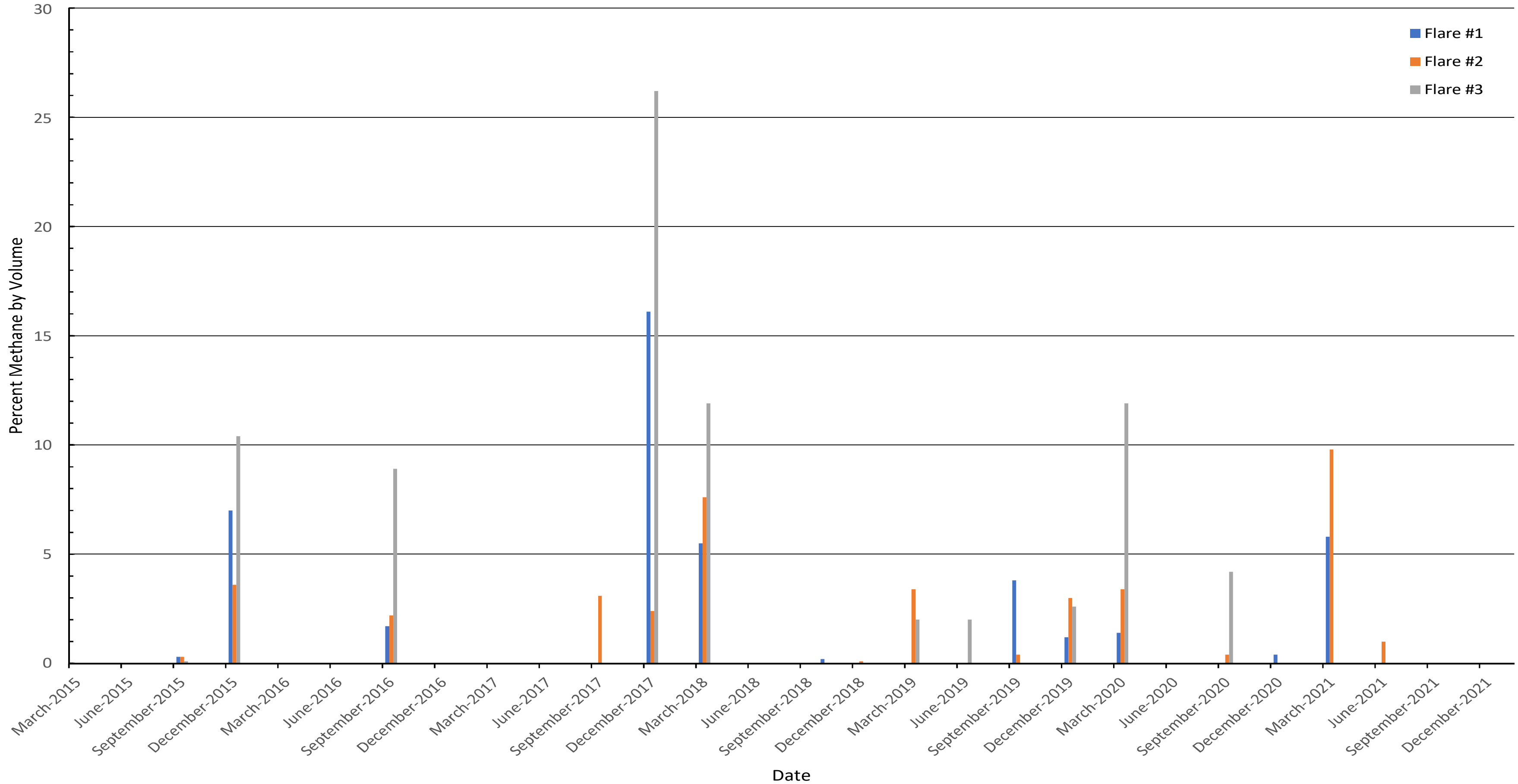

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FIGURE 5

OLALLA LANDFILL FLARE METHANE MEASUREMENTS

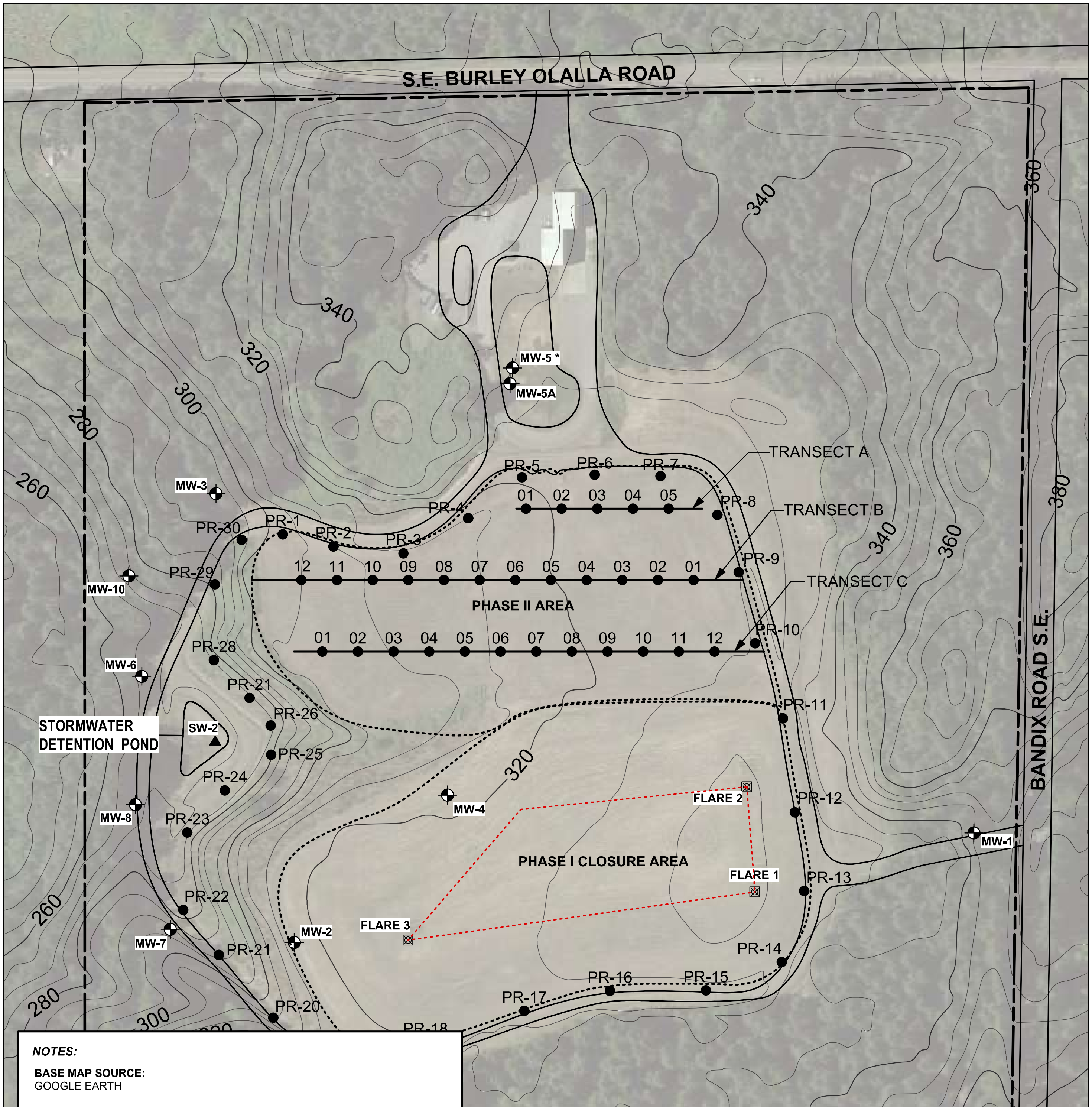
REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
429487

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 7/19/22
DRAWN BY .... AM
REVIEWED BY .... DCK



NOTES:

BASE MAP SOURCE:
GOOGLE EARTH

TOPOGRAPHIC CONTOUR SOURCE:
KITSAP COUNTY PARCEL VIEWER

*MW-5 IS COMPLETED IN A SHALLOW PERCHED GROUNDWATER ZONE

MW-2 MONITORING WELL LOCATION

PR-01 BAR HOLE SAMPLE LOCATION

SW-2 SURFACE WATER SAMPLING LOCATION

LANDFILL GAS FLARE

300 TOPOGRAPHIC ELEVATION CONTOUR

APPROXIMATE PROPERTY BOUNDARY

PERIMETER ACCESS ROAD

CLOSURE AREA BOUNDARIES

APPROXIMATE ALLIGNMENT OF UNDERGROUND PIPING SYSTEM

N

0 50 100 200

SCALE: 1" = 200'

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FIGURE 6

JANUARY 2022 BAR HOLE SURVEY LOCATIONS

REPORT
REMEDIAL ACTION STATUS REPORT

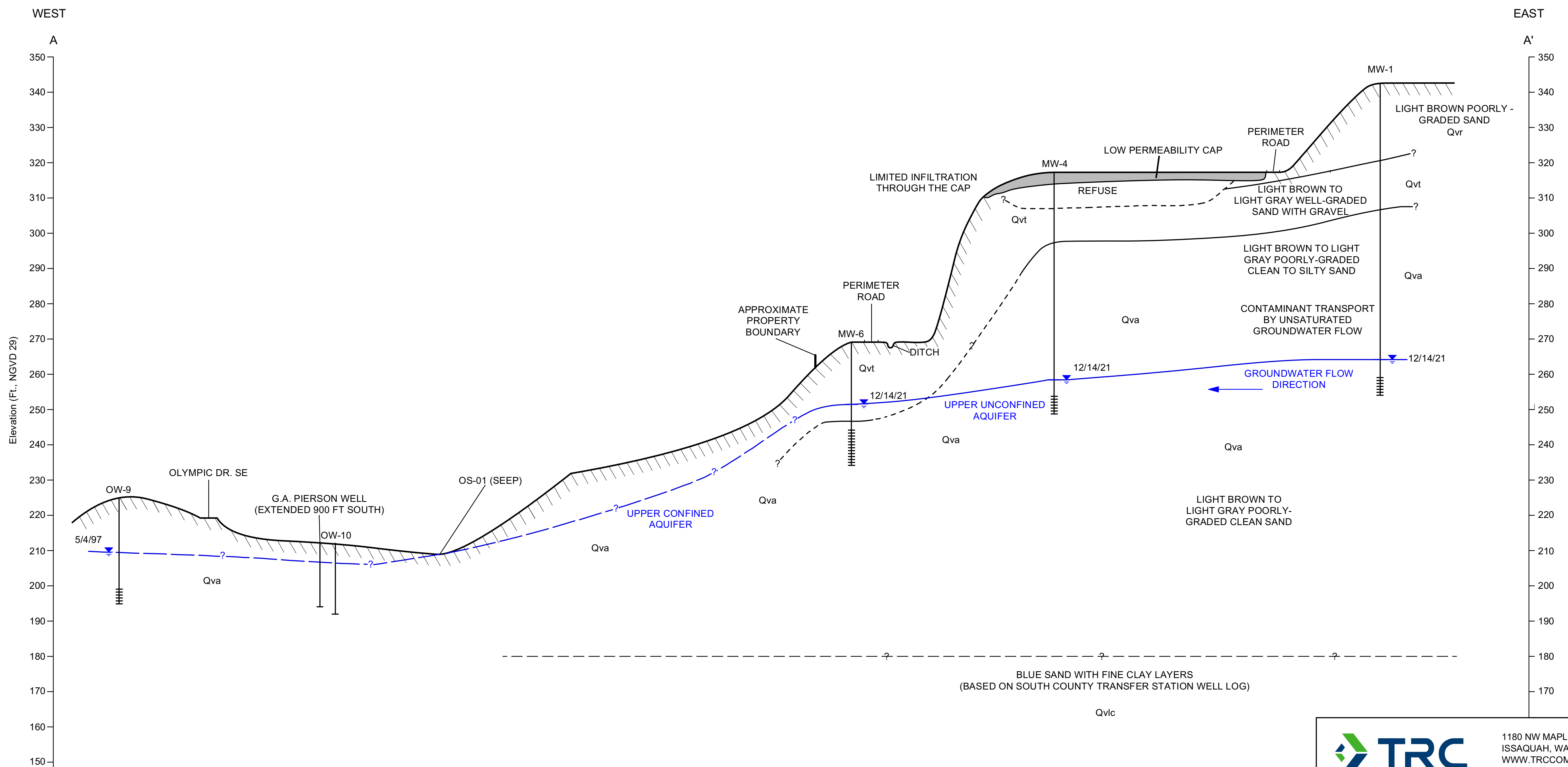
PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 7/19/22
DRAWN BY .... AM
REVIEWED BY .... DCK

Attachment A
Hydrogeologic Cross-Sections A-A' through D-D'



NOTES:

GROUND SURFACE

LITHOLOGIC CONTACT, DASHED WHERE INFERRED.

MONITORING WELL AND SCREENED INTERVAL

WATER LEVEL ON 12/14/21 UNLESS OTHERWISE NOTED

0 62.5 125 250

SCALE: 1" = 250'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

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HYDROGEOLOGIC CROSS-SECTION A - A'
KITSAP COUNTY, WASHINGTON

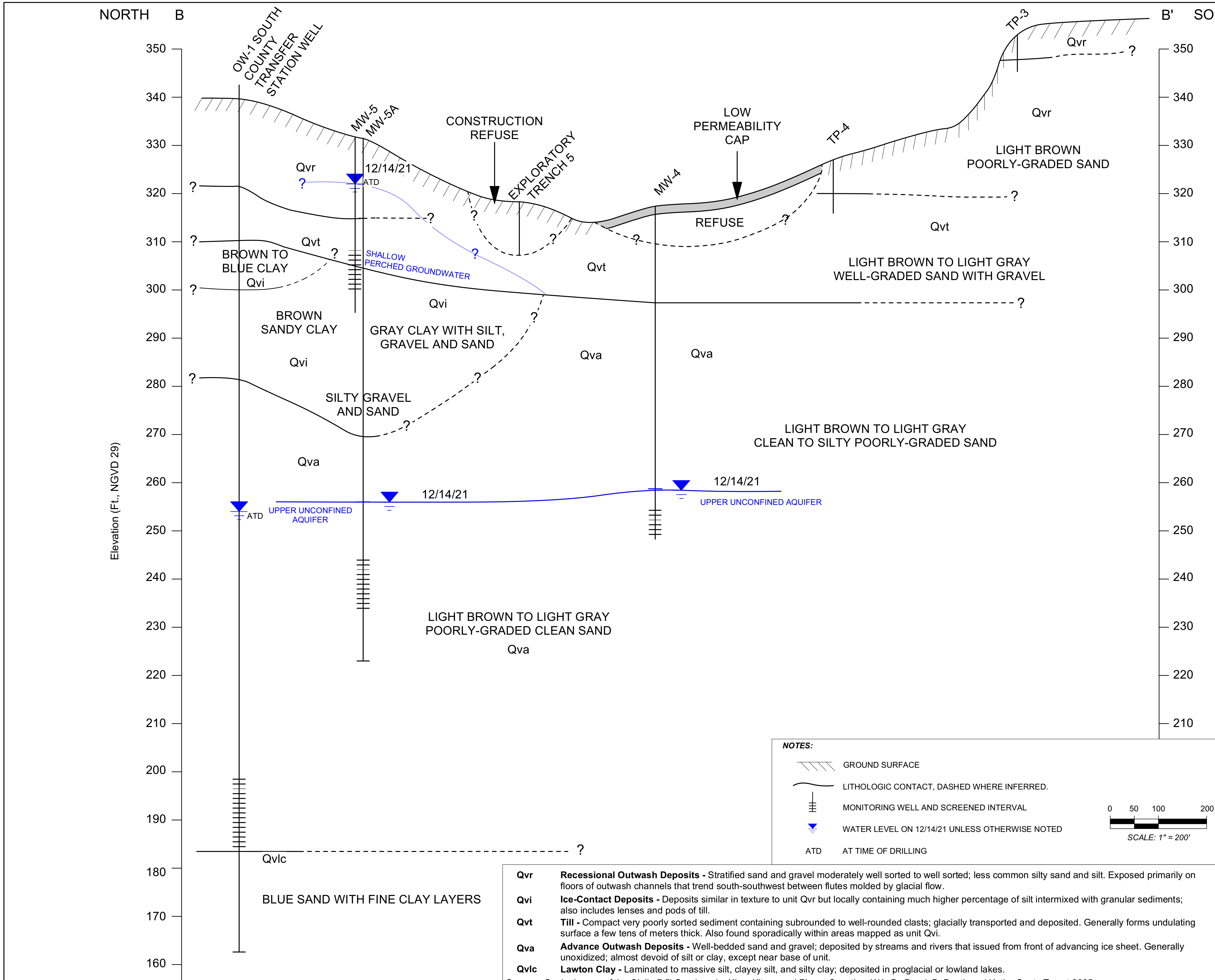
REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 6/16/22
DRAWN BY .... AM
REVIEWED BY .... DCK



NOTES:

- GROUND SURFACE
- LITHOLOGIC CONTACT, DASHED WHERE INFERRED.
- MONITORING WELL AND SCREENED INTERVAL
- WATER LEVEL ON 12/14/21 UNLESS OTHERWISE NOTED
- ATD AT TIME OF DRILLING

0 50 100 200

SCALE: 1" = 200'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

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HYDROGEOLOGIC CROSS-SECTION B - B'
KITSAP COUNTY, WASHINGTON

REPORT REMEDIAL ACTION STATUS REPORT

PREPARED FOR KITSAP COUNTY

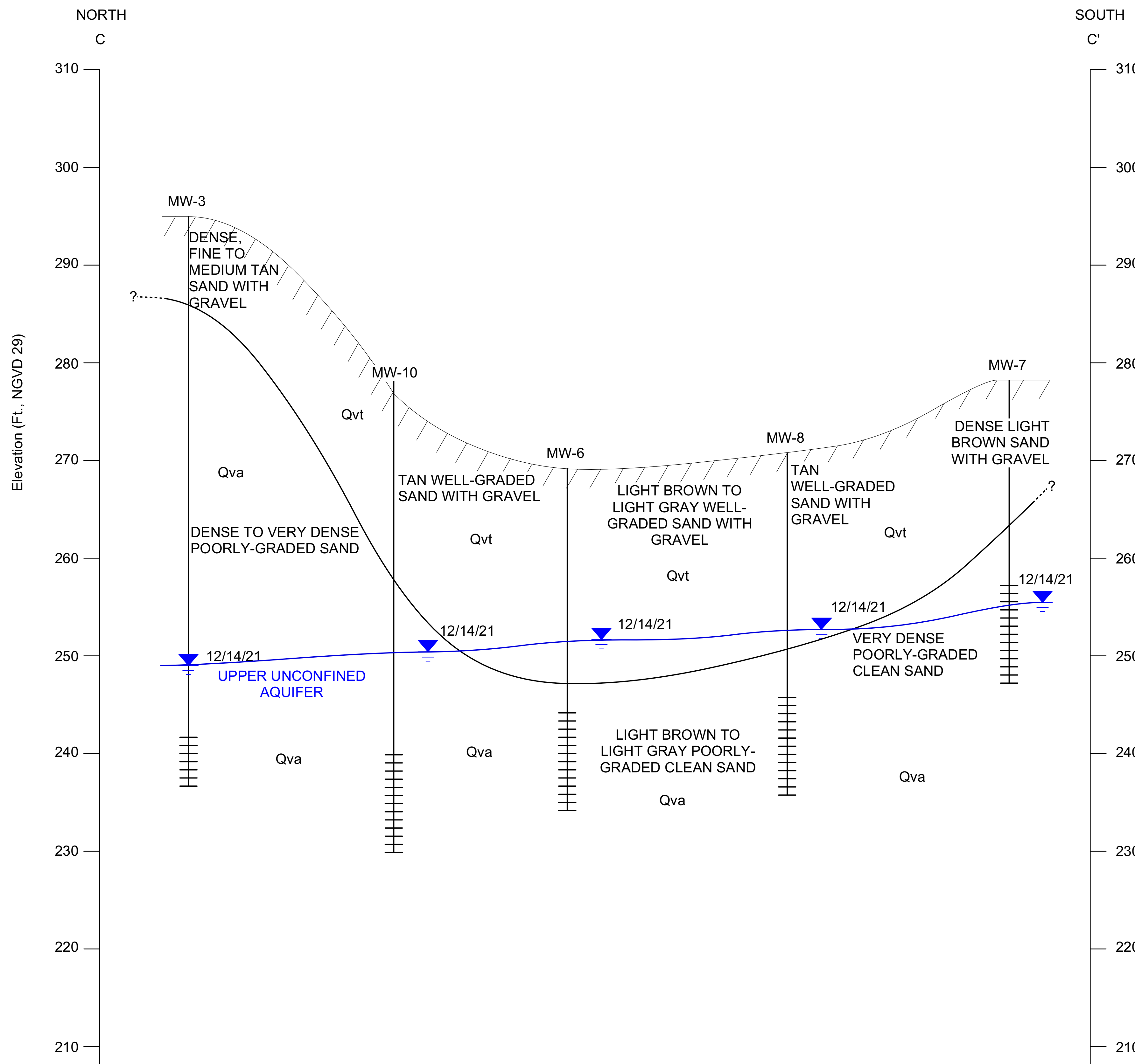
PROJECT NUMBER 382595

LOCATION OLALLA LANDFILL, KITSAP COUNTY, WASHINGTON

DATE 6/16/22

DRAWN BY AM

REVIEWED BY DCK



NOTES:

GROUND SURFACE

LITHOLOGIC CONTACT, DASHED WHERE INFERRED.

MONITORING WELL AND SCREENED INTERVAL

WATER LEVEL ON 12/14/21 UNLESS OTHERWISE NOTED

0 25 50 100

SCALE: 1" = 100'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

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HYDROGEOLOGIC CROSS-SECTION C - C'
KITSAP COUNTY, WASHINGTON

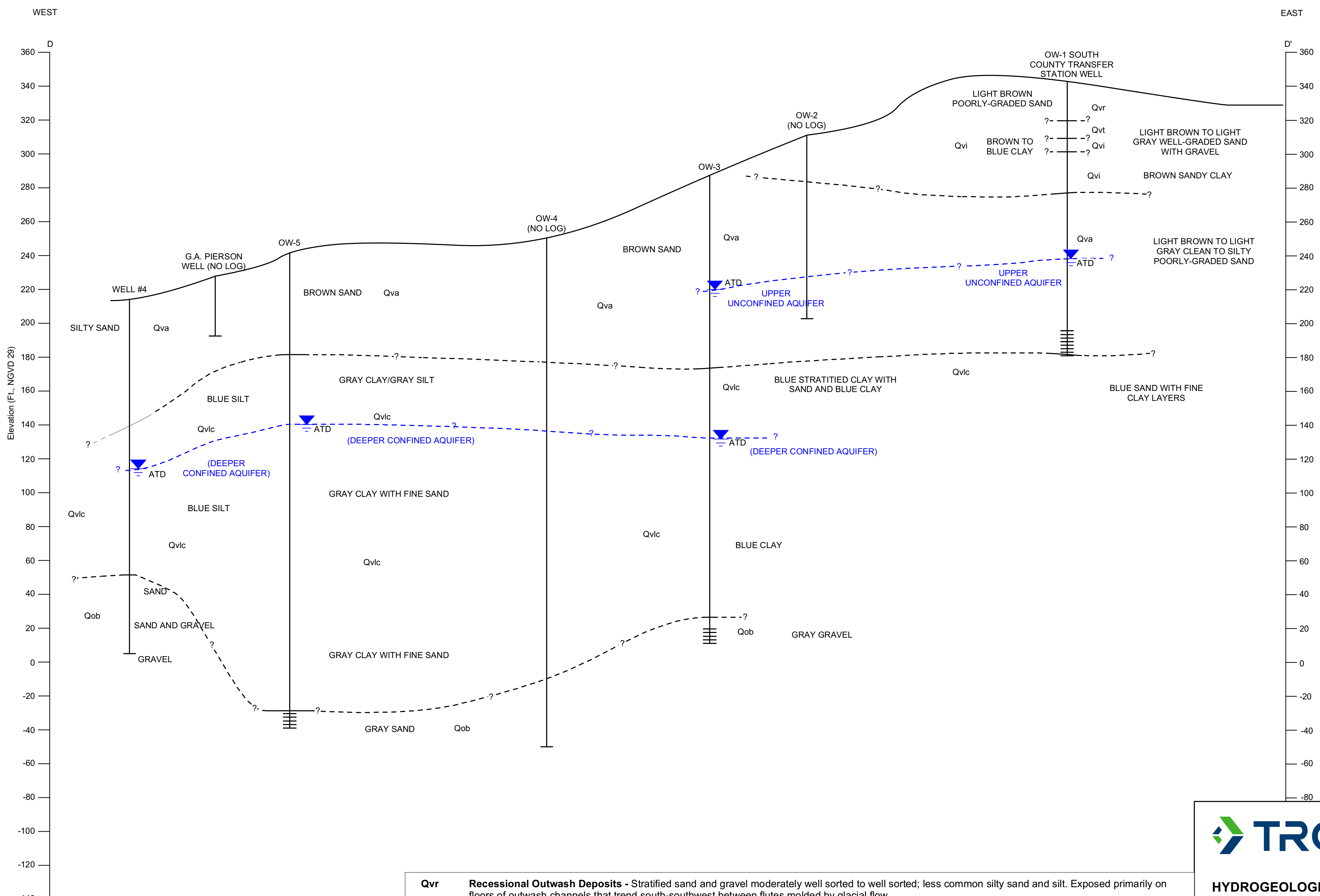
REPORT
REMEDIAL ACTION STATUS REPORT

PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 6/16/22
DRAWN BY AM
REVIEWED BY DCK



Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.
Qob	**Qlympia Beds of Minard and Booth -** Sand and silty thinly interbedded with some gravel layers and, locally, with abundant organic material; deposited by lowland streams or in floodplain and (or) lacustrine environments.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

NOTES:

GROUND SURFACE

LITHOLOGIC CONTACT, DASHED WHERE INFERRED.

MONITORING WELL AND SCREENED INTERVAL

ATD WATER LEVEL AT TIME OF DRILLING

0 31.25 62.5 125

SCALE: 1" = 125'

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HYDROGEOLOGIC CROSS-SECTION D - D'
KITSAP COUNTY, WASHINGTON

REPORT
REMEDIAL ACTION STATUS REPORT

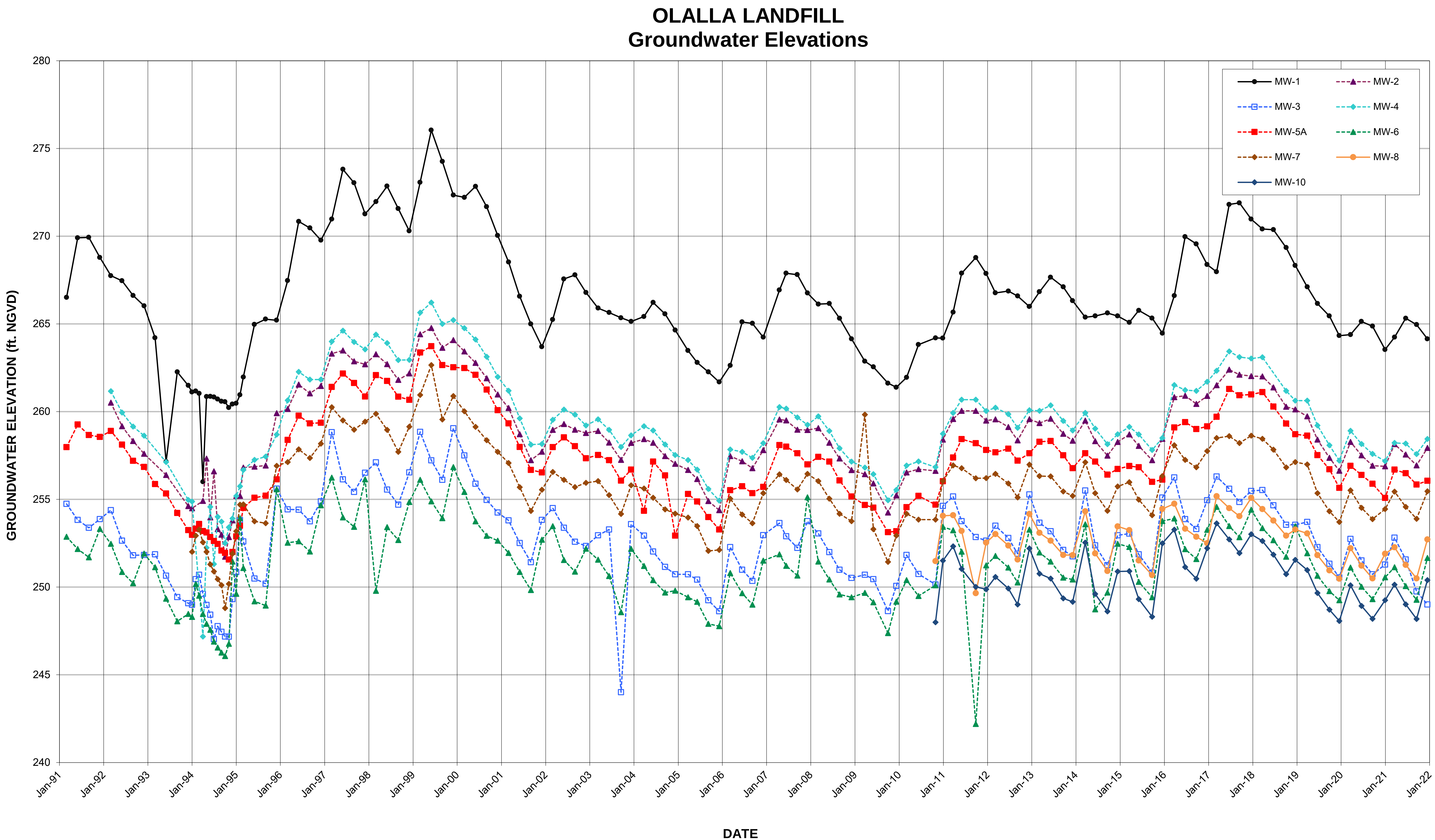
PREPARED FOR
KITSAP COUNTY

PROJECT NUMBER
382595

LOCATION
OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON

DATE 6/24/22
DRAWN BY .... AM
REVIEWED BY .... DCK

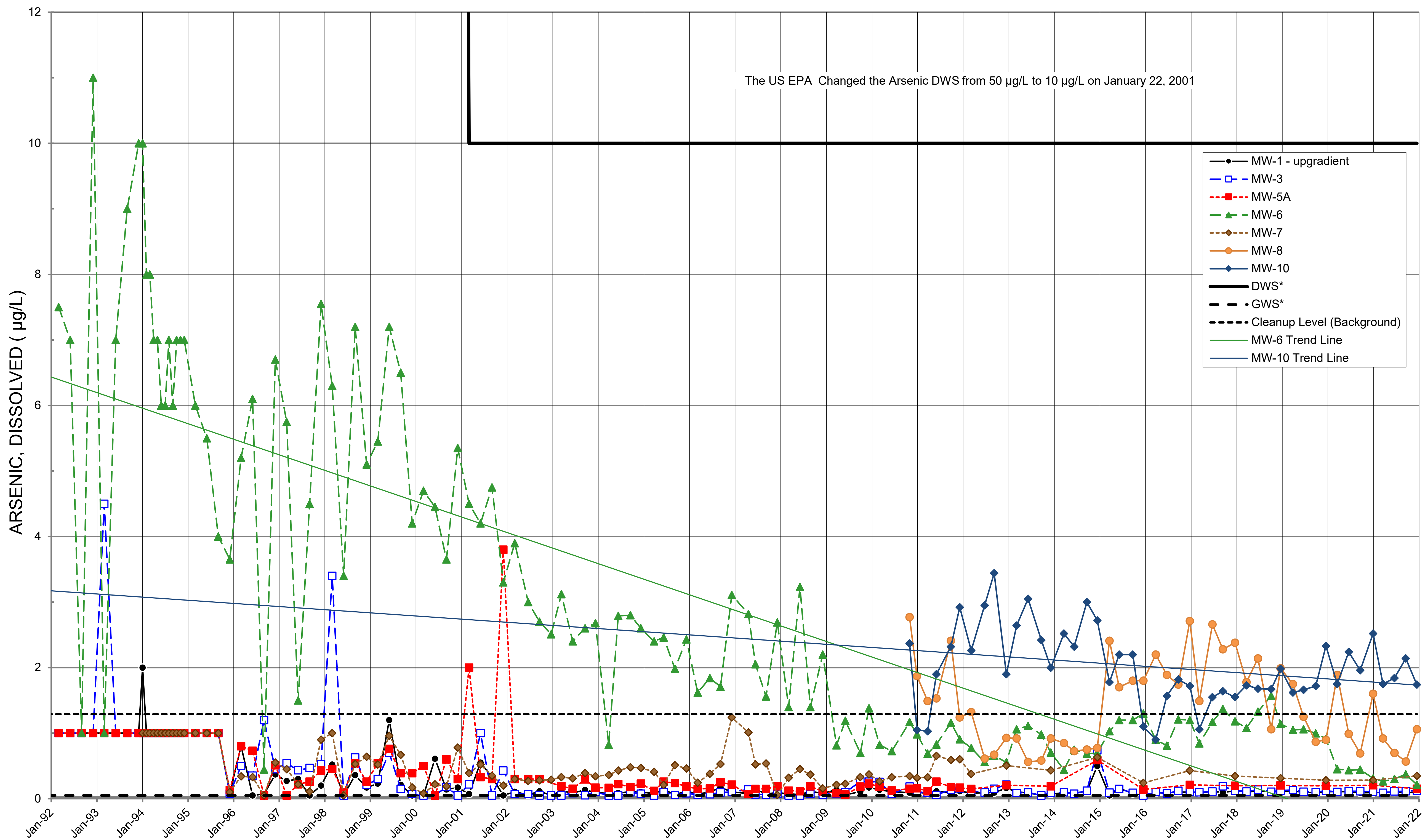
Attachment B
Historical Water Level Elevations in Monitoring Wells at Olalla Landfill



OLALLA LANDFILL
Groundwater Elevations
GROUNDWATER ELEVATION (ft. NGVD)
DATE
MW-1
MW-2
MW-3
MW-4
MW-5A
MW-6
MW-7
MW-8
MW-10
280
275
270
265
260
255
250
245
240
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
Jan-21
Jan-22

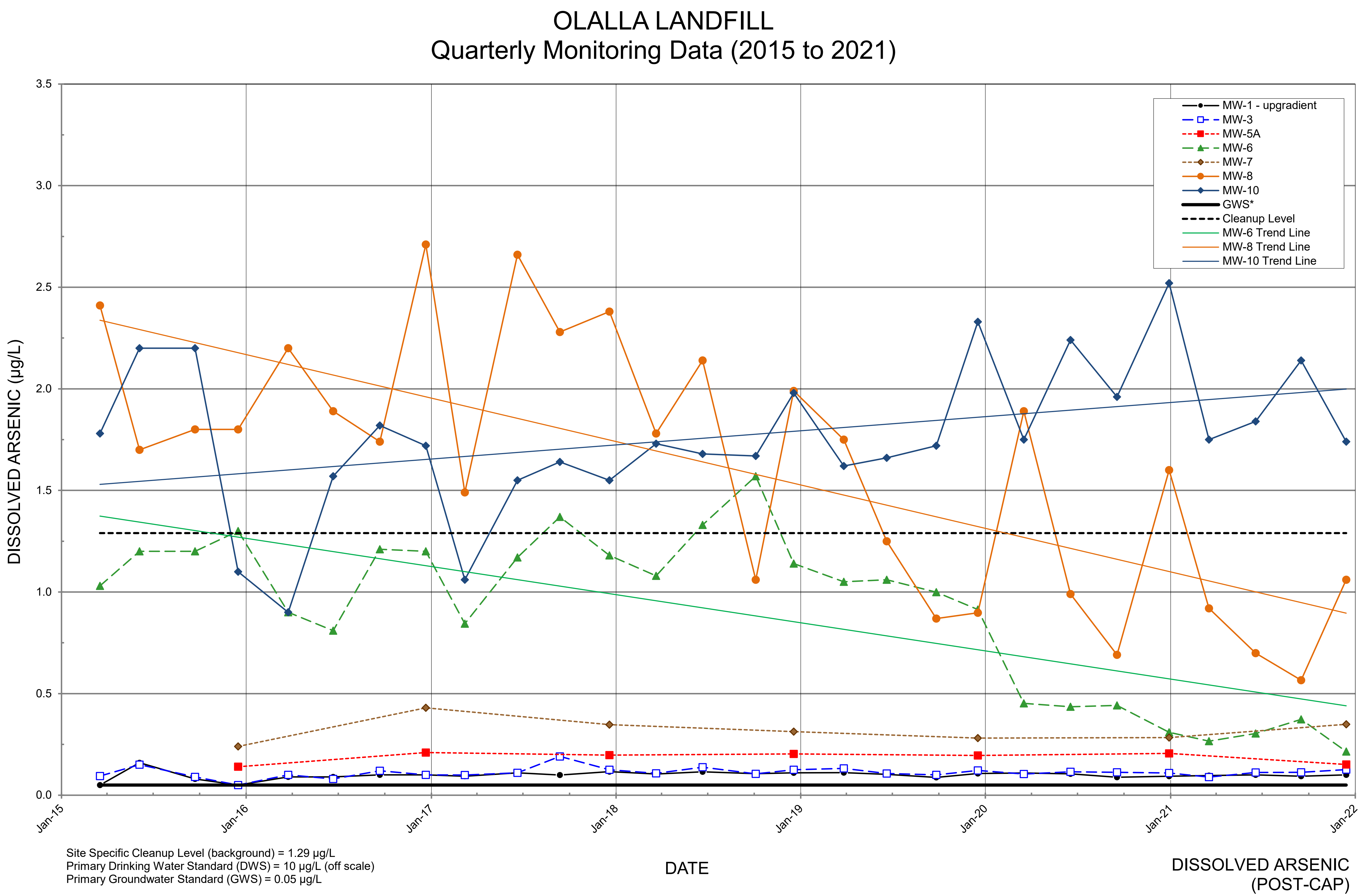
Attachment C
Time-Series Plots for Olalla Landfill Constituents of Concern

OLALLA LANDFILL
Quarterly Monitoring Data

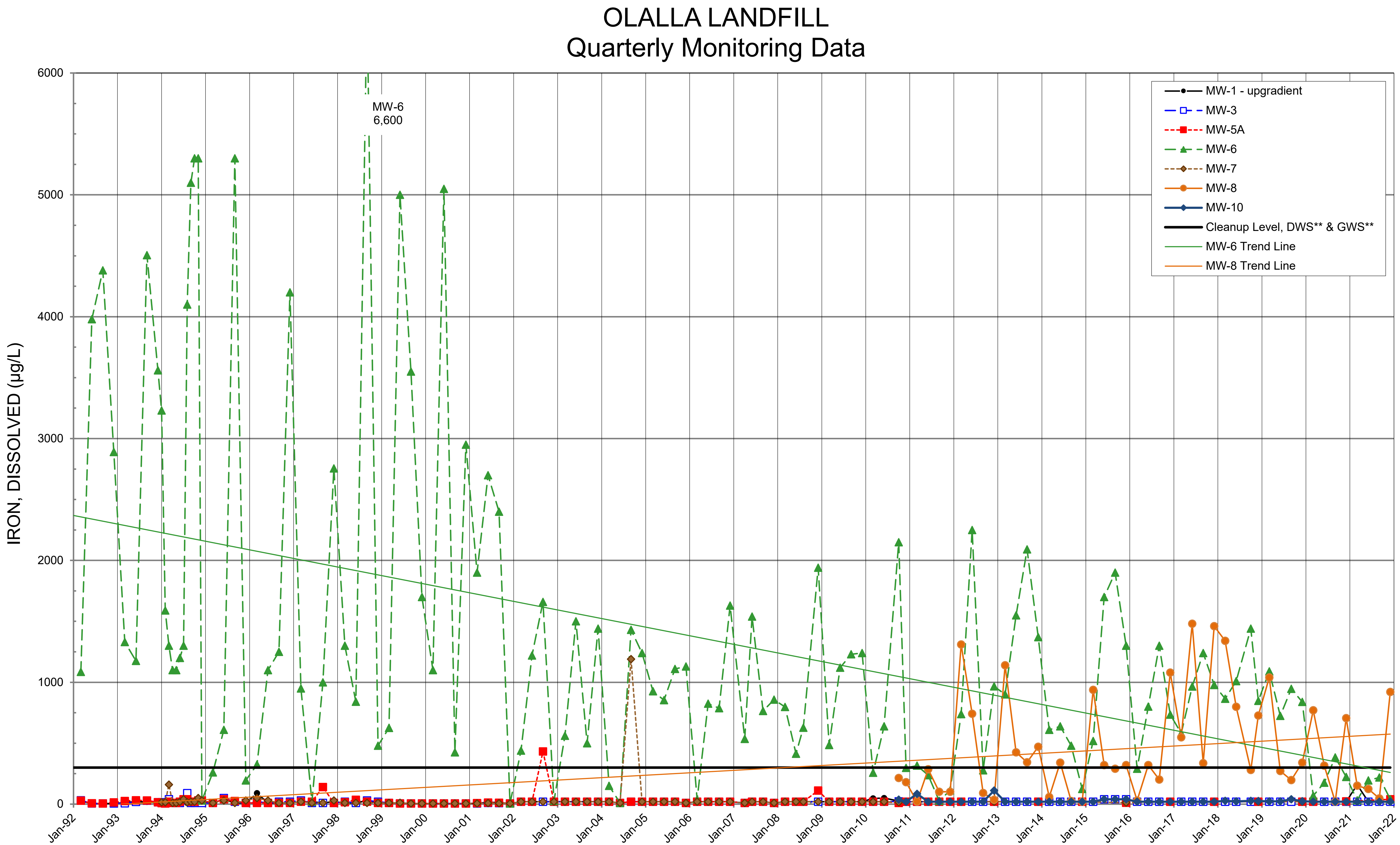


Cleanup Level (Background) = 1.29 ug/L
Primary Drinking Water Standard (DWS) = 10 µg/L
Primary Groundwater Standard (GWS) = 0.05 µg/L

DISSOLVED ARSENIC

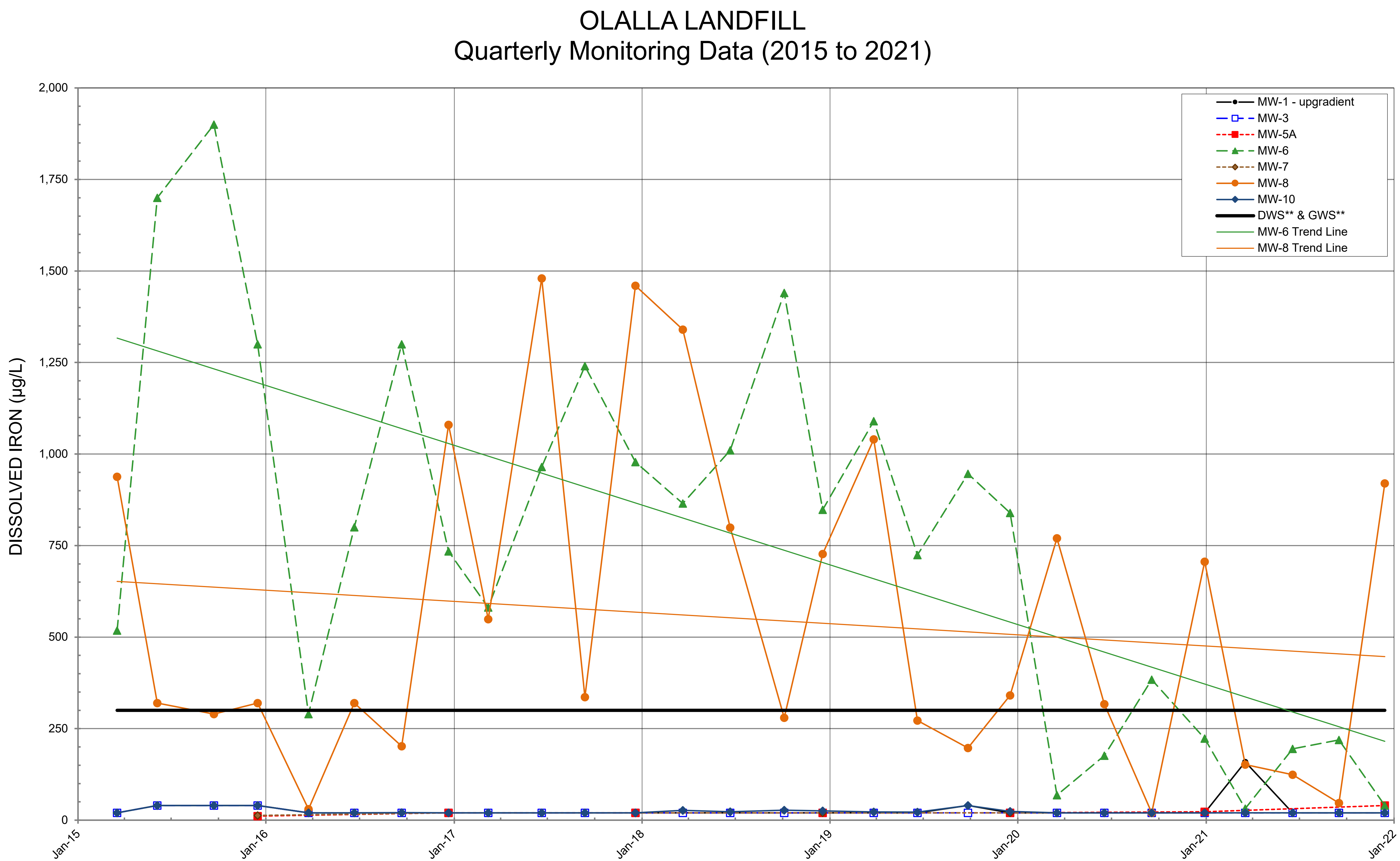


OLALLA LANDFILL
Quarterly Monitoring Data (2015 to 2021)
DISSOLVED ARSENIC (µg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
Jan-21
Jan-22
MW-1 - upgradient
MW-3
MW-5A
MW-6
MW-7
MW-8
MW-10
GWS*
Cleanup Level
MW-6 Trend Line
MW-8 Trend Line
MW-10 Trend Line
DATE
Site Specific Cleanup Level (background) = 1.29 µg/L
Primary Drinking Water Standard (DWS) = 10 µg/L (off scale)
Primary Groundwater Standard (GWS) = 0.05 µg/L
DISSOLVED ARSENIC
(POST-CAP)



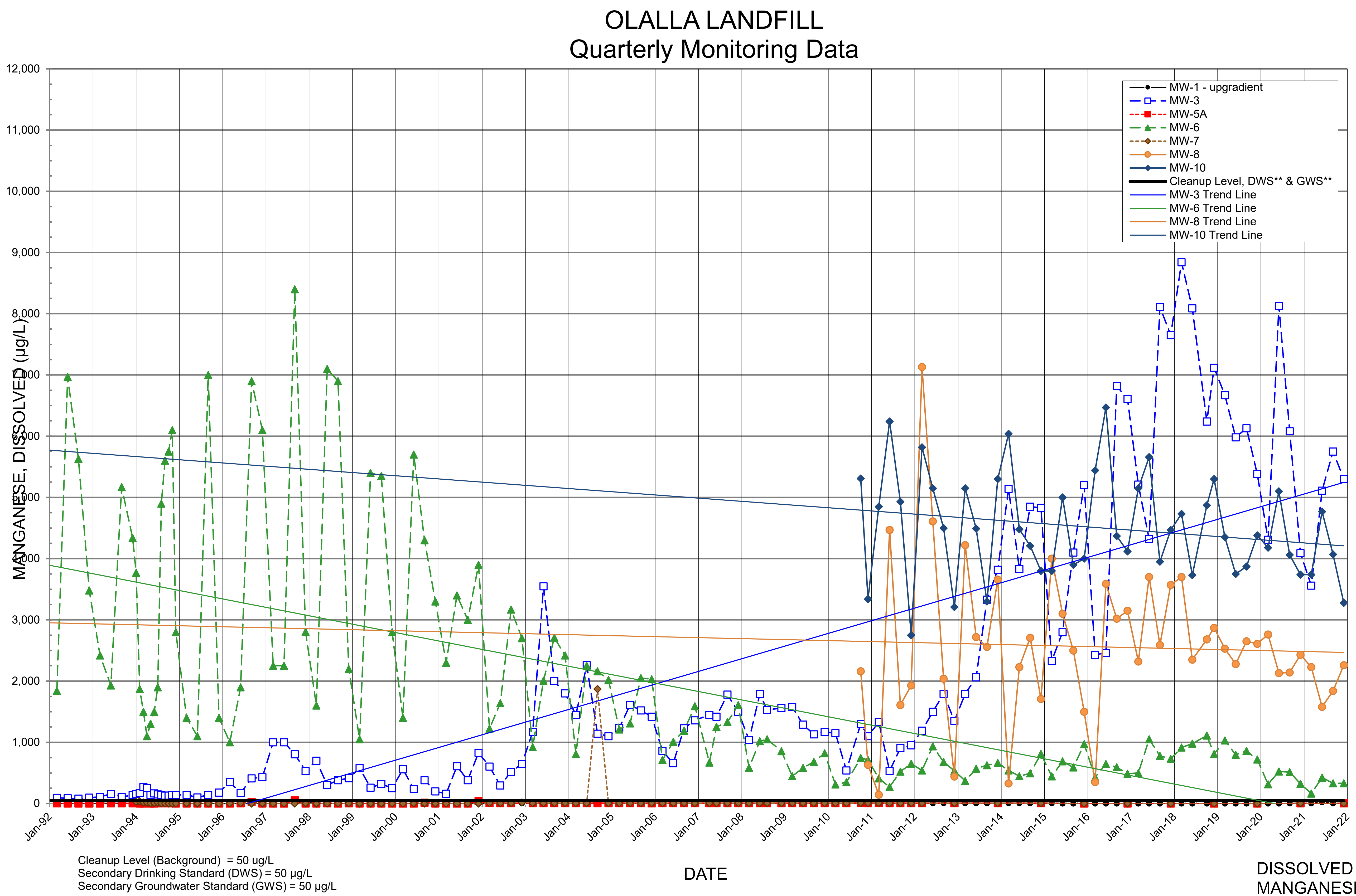
Cleanup Level = 300 µg/L
Secondary Drinking Water Standard (DWS) = 300 µg/L
Secondary Groundwater Standard (GWS) = 300 µg/L

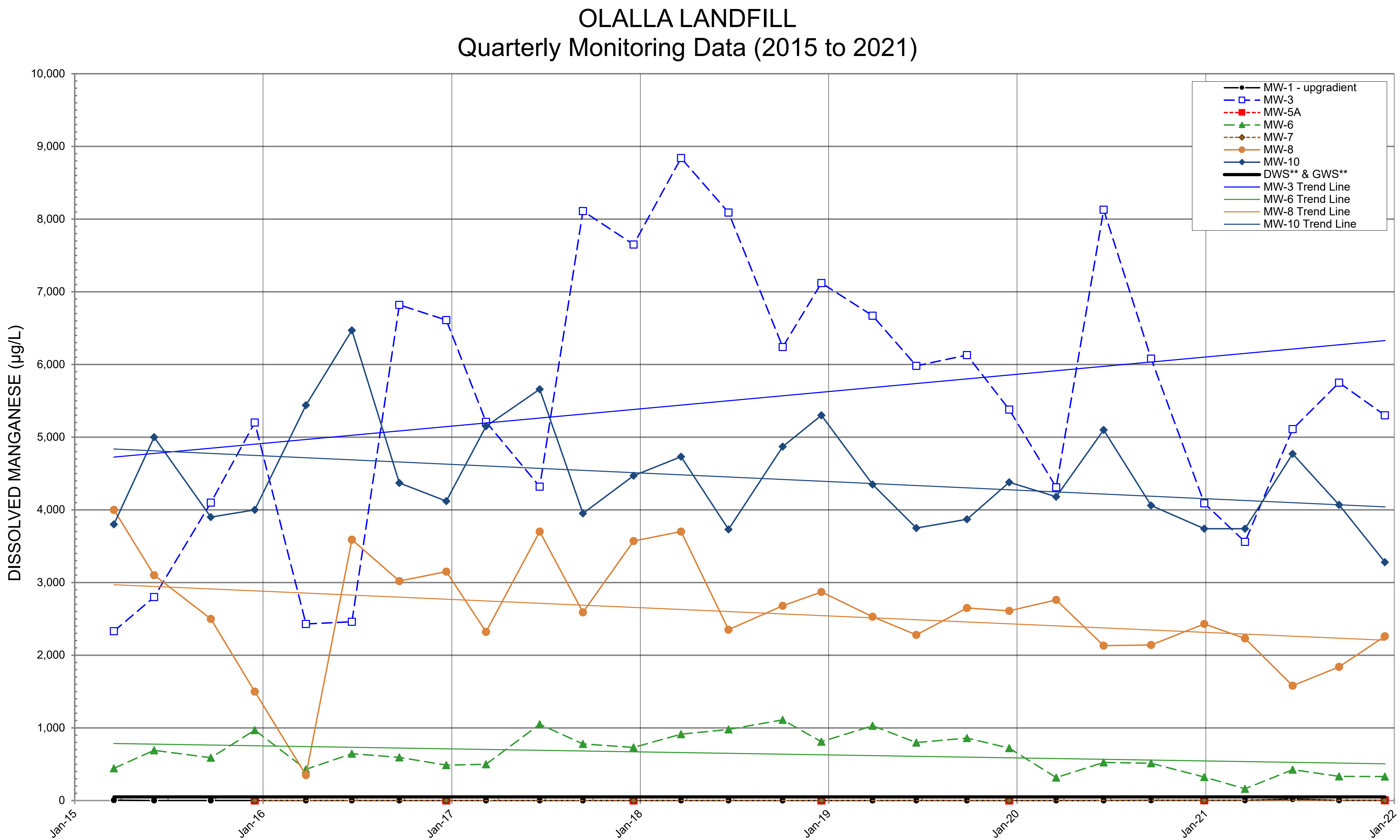
DISSOLVED
IRON



Site-Specific Cleanup Level = 300 µg/L
Secondary Drinking Water Standard (DWS) = 300 µg/L
Secondary Groundwater Standard (GWS) = 300 µg/L

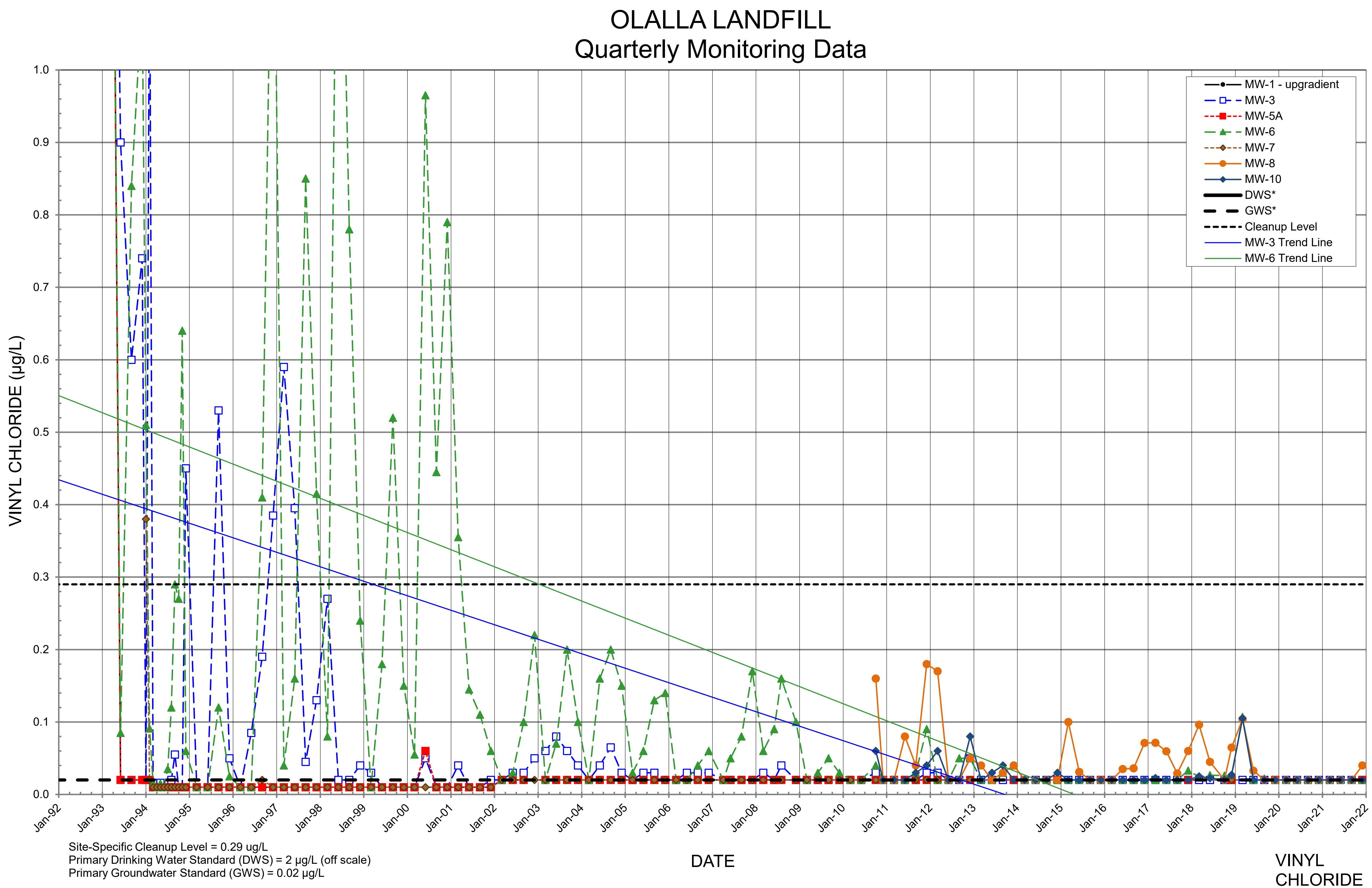
DISSOLVED IRON
(POST-CAP)


OLALLA LANDFILL
Quarterly Monitoring Data
MANGANESE, DISSOLVED (µg/L)
DATE
MW-1 - upgradient
MW-3
MW-5A
MW-6
MW-7
MW-8
MW-10
Cleanup Level, DWS** & GWS**
MW-3 Trend Line
MW-6 Trend Line
MW-8 Trend Line
MW-10 Trend Line
Cleanup Level (Background) = 50 ug/L
Secondary Drinking Standard (DWS) = 50 µg/L
Secondary Groundwater Standard (GWS) = 50 µg/L
DISSOLVED
MANGANESE



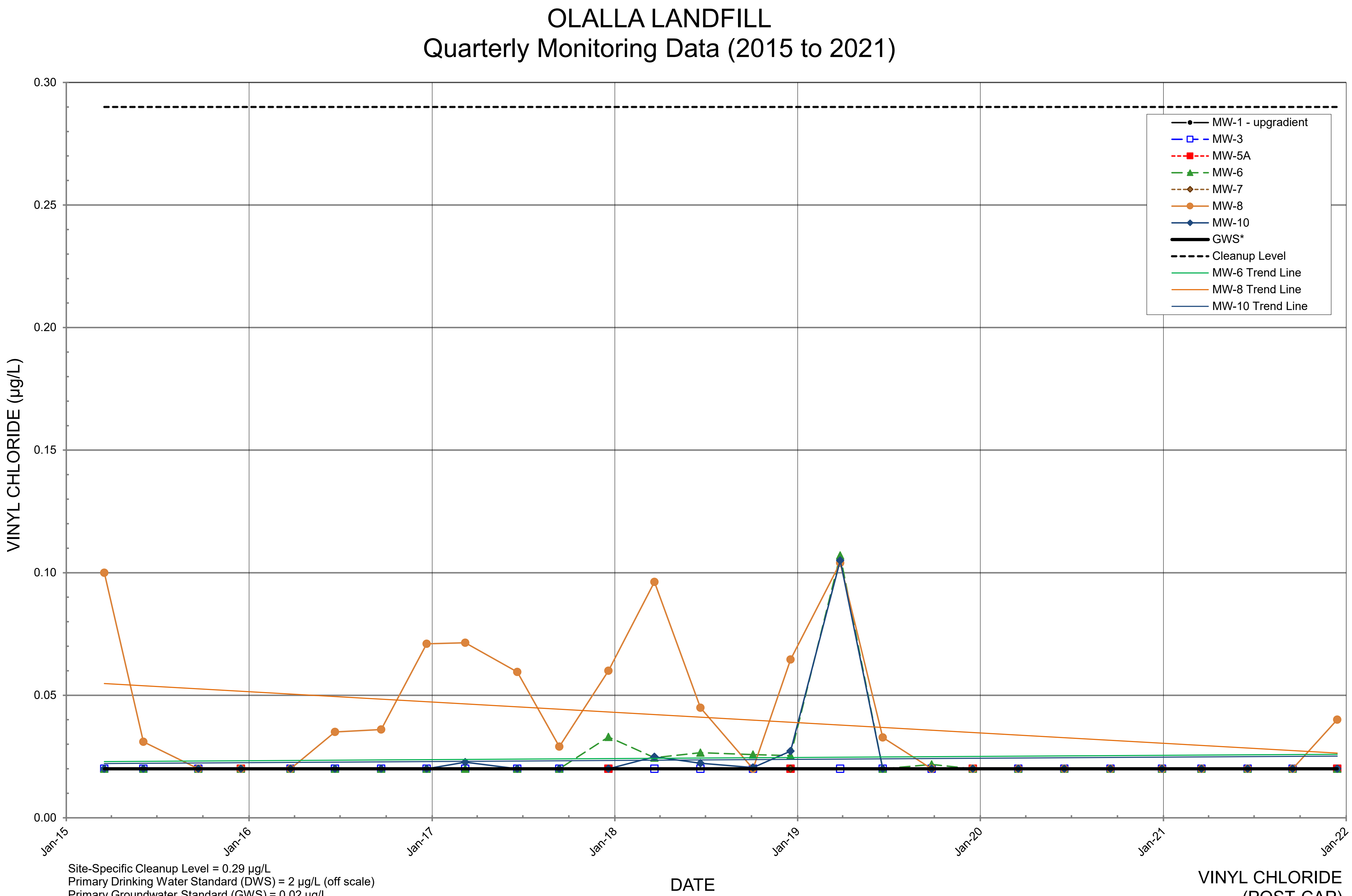
Site-specific Cleanup Level = 50 µg/L
Secondary Drinking Standard (DWS) = 50 µg/L
Secondary Groundwater Standard (GWS) = 50 µg/L

DISSOLVED MANGANESE
(POST-CAP)



Site-Specific Cleanup Level = 0.29 ug/L
Primary Drinking Water Standard (DWS) = 2 µg/L (off scale)
Primary Groundwater Standard (GWS) = 0.02 µg/L

VINYL
CHLORIDE

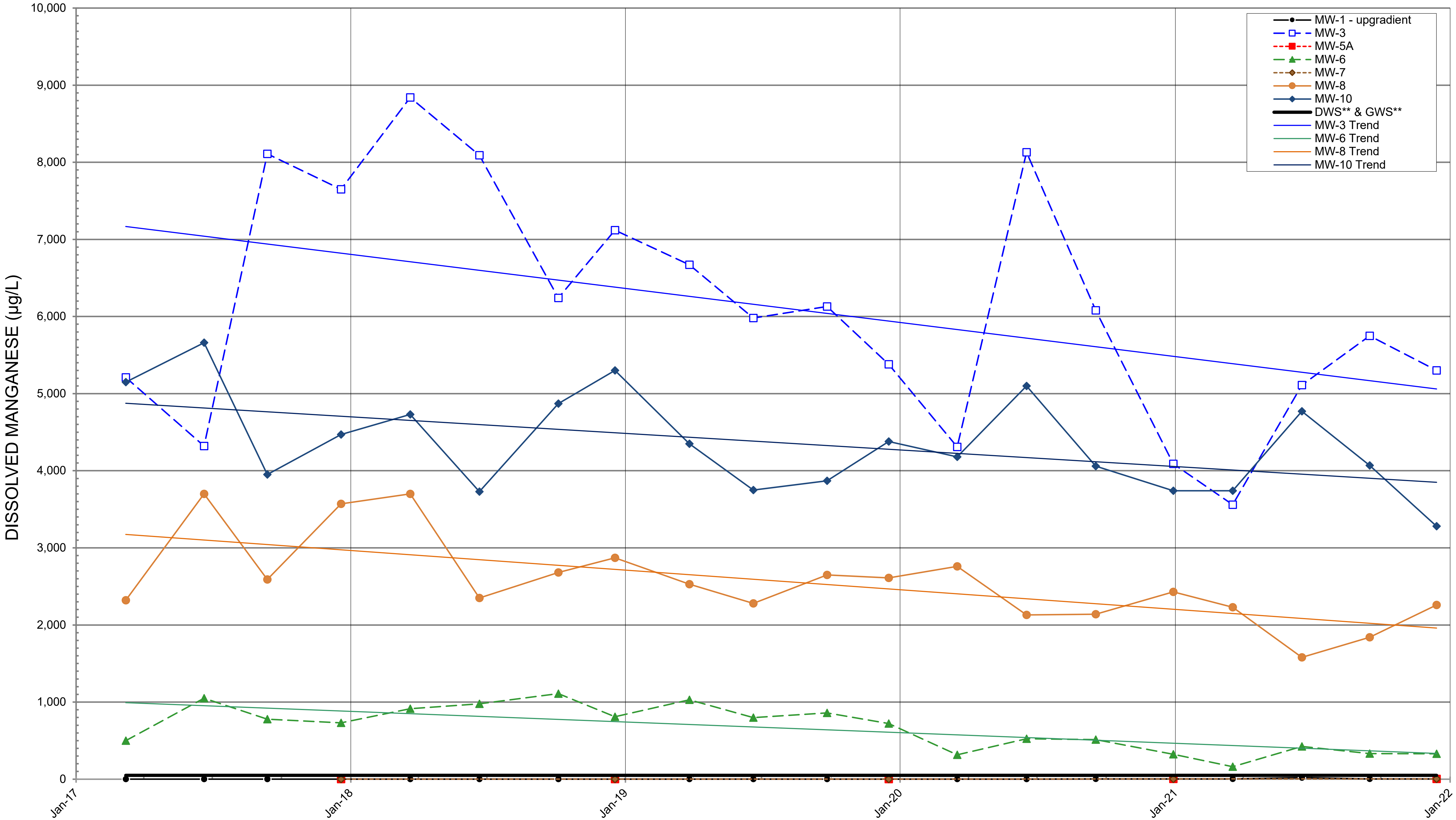


Site-Specific Cleanup Level = 0.29 µg/L
Primary Drinking Water Standard (DWS) = 2 µg/L (off scale)
Primary Groundwater Standard (GWS) = 0.02 µg/L

VINYL CHLORIDE
(POST-CAP)

Attachment D
5-Year Manganese Time-Series Plot

OLALLA LANDFILL
Quarterly Monitoring Data (most recent five years)



Site-specific Cleanup Level = 50 µg/L
Secondary Drinking Standard (DWS) = 50 µg/L
Secondary Groundwater Standard (GWS) = 50 µg/L

DISSOLVED MANGANESE
(RECENT)

Attachment E
Olalla Landfill Inspection Forms and Reports

KITSAP COUNTY DEPARTMENT OF PUBLIC WORKS
614 DIVISION STREET (MS-26), PORT ORCHARD, WA 98366-4699 | KITSAP1: 360.337.5777 | KITSAPGOV.COM

MEMORANDUM

To: Alexis McKinnon

From: Kenneth Swindaman, PLS/Kitsap County Surveyor KWS

CC: File

Date: June 22, 2020

Subject: Survey procedures establishing values on monitoring points

The survey group within the Department of Public Works, Roads Engineering, established monitoring points on the surface of the closed Olalla landfill. We reviewed various methods to establish permanent points to monitor any possible movement on the surface of the closed landfill. To ensure monitoring stations would not penetrate beyond the top six inches of the top layer of the landfill surface, an 18 inch by 6-inch-deep concrete point was installed. A domed survey brass cap was installed on the surface of the concrete filled monitoring stations. The brass cap was stamped with monitoring number and a punch mark for all future observations.

Kitsap County survey staff established primary site survey control along the perimeter roads. GPS survey methods were used to establish both horizontal and vertical control values for each survey control point. Each primary control point was occupied with a 4-hour GPS session. The GPS sessions data was submitted to National Geodetic Survey using OPUS (Online Position User Service). This service provides horizontal and vertical results for each point.

Kitsap County survey staff established horizontal coordinates on each monitoring point. This was accomplished using a Leica TS50 total station. Each monitoring point was located from two different control stations and a mean of the two coordinate values was calculated. The largest difference between the two values was no greater than 0.03' or approximately 5/16 of an inch. Elevations were established utilizing a Trimble DiNi digital level. The elevation error between primary survey control was no greater than 0.02' or approximately 1/4 of an inch.

If there are any additional questions you may have please let me know and I will try to provide as much information as possible.

KITSAP COUNTY DEPARTMENT OF PUBLIC WORKS
614 DIVISION STREET (MS-26), PORT ORCHARD, WA 98366-4699 | KITSAP1: 360.337.5777 | KITSAPGOV.COM

MEMORANDUM

To: Alexis McKinnon

From: Kenneth Swindaman, PLS/Kitsap County Surveyor

CC: File

Date: December 16, 2020

Subject: Olalla Landfill Monitoring Points Observations

Monitoring stations were installed on the surface of Olalla Landfill in July 2019. Kitsap County survey staff established initial horizontal coordinates and elevations on each monitoring point.

Our staff established new coordinate and elevations on each monitoring points in December 2020.

Page 2 of this document contains the 2019 and 2020 results. The differences from these two readings are also reported on the noted page.

If you have any questions, please let me know.

	July 2019 Observations			December 2020 Observations			Observation differences		
Point	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	▲ NORTHING	▲ EASTING	▲ ELEVATION
1	162217.713	1200261.524	323.86	162217.716	1200261.540	323.85	0.003	0.016	-0.01
2	162194.869	1200125.457	322.20	162194.875	1200125.479	322.19	0.005	0.022	-0.01
3	162172.002	1199989.476	316.39	162172.013	1199989.490	316.35	0.011	0.014	-0.04
4	162149.109	1199853.827	312.02	162149.119	1199853.830	312.01	0.010	0.003	-0.01
5	162126.693	1199717.100	305.96	162126.690	1199717.115	305.94	-0.003	0.015	-0.01
6	161986.959	1199741.122	306.60	161986.961	1199741.132	306.59	0.002	0.010	-0.01
7	162009.592	1199876.935	310.35	162009.622	1199876.949	310.35	0.030	0.014	0.00
8	162032.166	1200012.926	316.50	162032.173	1200012.943	316.49	0.007	0.017	0.00
9	162054.919	1200148.790	321.48	162054.924	1200148.808	321.48	0.005	0.018	0.00
10	162077.396	1200284.999	324.52	162077.385	1200285.012	324.51	-0.011	0.013	-0.01
11	161937.598	1200308.020	327.31	161937.588	1200308.026	327.29	-0.010	0.006	-0.01
12	161915.112	1200172.343	323.62	161915.118	1200172.359	323.61	0.006	0.016	-0.01
13	161892.409	1200036.159	319.45	161892.400	1200036.161	319.45	-0.009	0.002	0.00
14	161869.677	1199900.175	316.39	161869.693	1199900.189	316.39	0.016	0.014	0.00
15	161729.745	1199923.746	321.49	161729.748	1199923.745	321.47	0.003	-0.001	-0.02
16	161752.377	1200059.494	323.24	161752.390	1200059.480	323.23	0.013	-0.014	-0.01
17	161775.103	1200195.616	326.65	161775.128	1200195.614	326.63	0.025	-0.002	-0.02
18	161797.681	1200331.391	330.31	161797.688	1200331.406	330.29	0.006	0.015	-0.02
19	161658.009	1200354.822	332.84	161658.026	1200354.821	332.84	0.017	-0.001	0.00
20	161635.013	1200218.615	328.18	161635.030	1200218.635	328.16	0.017	0.020	-0.02
21	161612.728	1200082.860	325.43	161612.745	1200082.856	325.43	0.017	-0.004	0.00
22	161589.583	1199946.472	322.91	161589.613	1199946.475	322.89	0.030	0.003	-0.01
23	161567.450	1199810.977	321.93	161567.470	1199810.980	321.93	0.020	0.003	0.00
24	161706.987	1199787.599	320.91	161707.007	1199787.612	320.89	0.019	0.013	-0.02
25	161825.139	1199907.237	318.79	161825.158	1199907.256	318.77	0.019	0.018	-0.02

KITSAP COUNTY DEPARTMENT OF PUBLIC WORKS
614 DIVISION STREET (MS-26), PORT ORCHARD, WA 98366-4699 | KITSAP1: 360.337.5777 | KITSAPGOV.COM

MEMORANDUM

To: Alexis McKinnon

From: Kenneth Swindaman, PLS/Kitsap County Surveyor

CC: File

Date: December 16, 2020

Subject: Olalla Landfill Monitoring Points Observations

Monitoring stations were installed on the surface of Olalla Landfill in July 2019. Kitsap County survey staff established initial horizontal coordinates and elevations on each monitoring point.

Our staff established new coordinate and elevations on each monitoring points in December 2020.

Page 2 of this document contains the 2019 and 2020 results. The differences from these two readings are also reported on the noted page.

If you have any questions, please let me know.

KITSAP COUNTY DEPARTMENT OF PUBLIC WORKS

614 DIVISION STREET (MS-26), PORT ORCHARD, WA 98366-4699 | KITSAP1: 360.337.5777 | KITSAPGOV.COM

	July 2019 Observations			December 2020 Observations			Observation differences		
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1	162217.713	1200261.524	323.86	162217.716	1200261.540	323.85	0.003	0.016	-0.01
2	162194.869	1200125.457	322.20	162194.875	1200125.479	322.19	0.005	0.022	-0.01
3	162172.002	1199989.476	316.39	162172.013	1199989.490	316.35	0.011	0.014	-0.04
4	162149.109	1199853.827	312.02	162149.119	1199853.830	312.01	0.010	0.003	-0.01
5	162126.693	1199717.100	305.96	162126.690	1199717.115	305.94	-0.003	0.015	-0.01
6	161986.959	1199741.122	306.60	161986.961	1199741.132	306.59	0.002	0.010	-0.01
7	162009.592	1199876.935	310.35	162009.622	1199876.949	310.35	0.030	0.014	0.00
8	162032.166	1200012.926	316.50	162032.173	1200012.943	316.49	0.007	0.017	0.00
9	162054.919	1200148.790	321.48	162054.924	1200148.808	321.48	0.005	0.018	0.00
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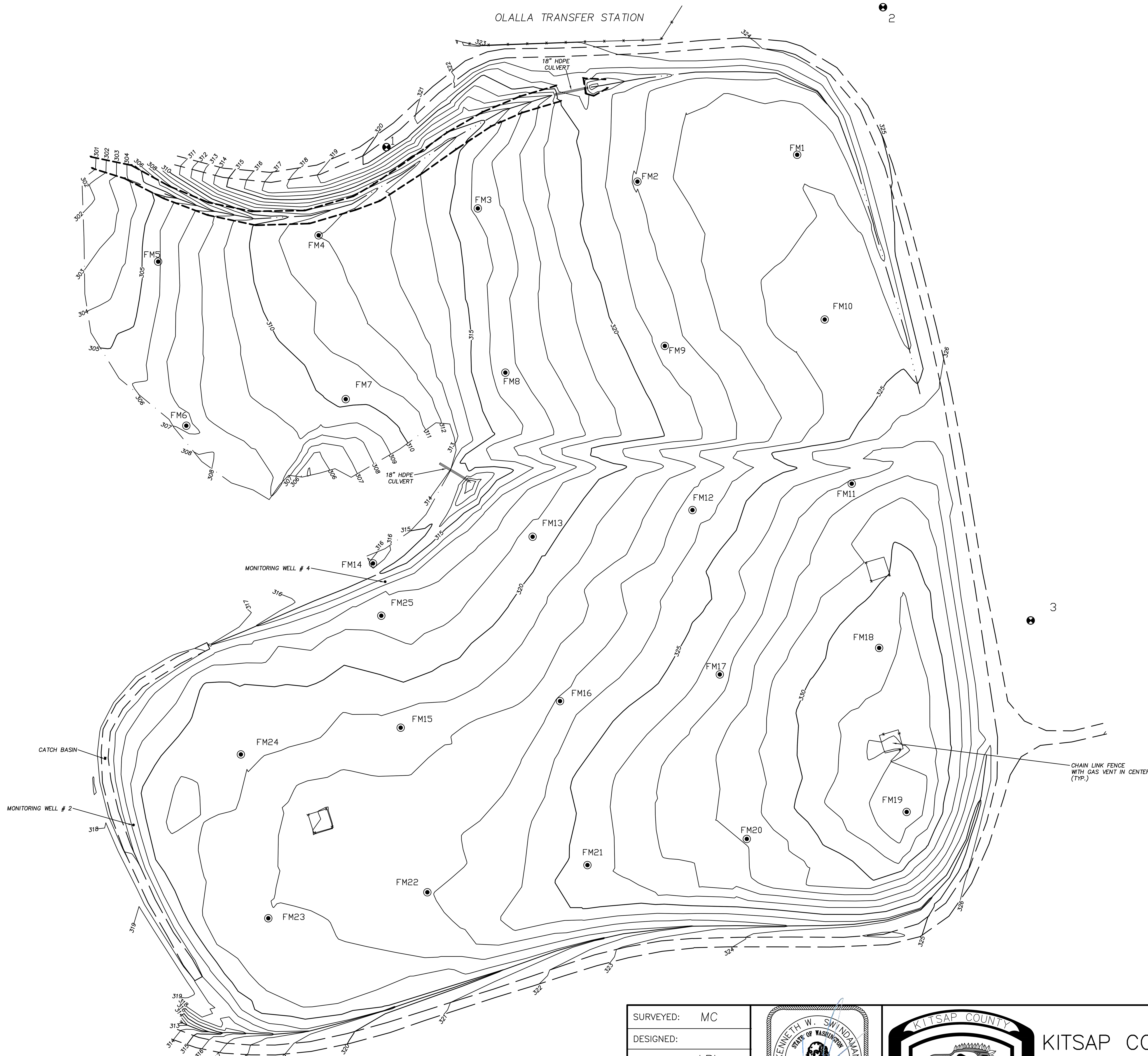
11	161937.598	1200308.020	327.31	161937.588	1200308.026	327.29	-0.010	0.006	-0.01
12	161915.112	1200172.343	323.62	161915.118	1200172.359	323.61	0.006	0.016	-0.01
13	161892.409	1200036.159	319.45	161892.400	1200036.161	319.45	-0.009	0.002	0.00
14	161869.677	1199900.175	316.39	161869.693	1199900.189	316.39	0.016	0.014	0.00
15	161729.745	1199923.746	321.49	161729.748	1199923.745	321.47	0.003	-0.001	-0.02
16	161752.377	1200059.494	323.24	161752.390	1200059.480	323.23	0.013	-0.014	-0.01
17	161775.103	1200195.616	326.65	161775.128	1200195.614	326.63	0.025	-0.002	-0.02
18	161797.681	1200331.391	330.31	161797.688	1200331.406	330.29	0.006	0.015	-0.02
19	161658.009	1200354.822	332.84	161658.026	1200354.821	332.84	0.017	-0.001	0.00
20	161635.013	1200218.615	328.18	161635.030	1200218.635	328.16	0.017	0.020	-0.02
21	161612.728	1200082.860	325.43	161612.745	1200082.856	325.43	0.017	-0.004	0.00
22	161589.583	1199946.472	322.91	161589.613	1199946.475	322.89	0.030	0.003	-0.01
23	161567.450	1199810.977	321.93	161567.470	1199810.980	321.93	0.020	0.003	0.00
24	161706.987	1199787.599	320.91	161707.007	1199787.612	320.89	0.019	0.013	-0.02
25	161825.139	1199907.237	318.79	161825.158	1199907.256	318.77	0.019	0.018	-0.02

SECTION 1, TOWNSHIP 22, NORTH, RANGE 1 EAST, W.M.
KITSAP COUNTY, WASHINGTON



Survey Notes:

Base map prepared by Kitsap County Public Works Survey Department August 2019, from field survey data gathered July 2019.

Horizontal Datum: NAD83(2011) (2010 EPOCH) Washington State Plane Coordinate System-(North Zone) based upon two 1-hour GPS observations submitted to National Geodetic Survey using the OPUS solution service.

Vertical Datum: NAVD88 (GEOID12B) based upon two 1-hour GPS observations submitted to National Geodetic Survey using the OPUS solution service.

Monitoring point horizontal locations were derived from the averaging of two independent horizontal measurements from control points listed with a Leica MS 50 Total Station.

Monitoring point elevations were derived from differential leveling using a Trimble DiNi digital level. Control point number 1 was held as the site benchmark.

Contour Interval is one-foot and are computer generated from ground field topography gathered for this survey utilizing electronic data collection.

Subsurface utility lines were not marked and are not shown on base map. Utility surface features were located and shown.

Horizontal coordinates listed are US Survey feet, GRID.

CONTROL POINTS

Point	Northing	Easting	Elevation
1	162224.197	1199911.635	320.47
2	162343.388	1200334.668	324.30
3	161821.069	1200460.479	335.26

MONITORING POINTS

Point	Northing	Easting	Elevation
FM1	162217.713	1200261.524	323.86
FM2	162194.869	1200125.457	322.20
FM3	162172.002	1199989.476	316.39
FM4	162149.109	1199853.827	312.02
FM5	162126.693	1199717.100	305.96
FM6	161986.959	1199741.122	306.60
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FM8	162032.166	1200012.926	316.50
FM9	162054.919	1200148.790	321.48
FM10	162077.396	1200284.999	324.52
FM11	161937.598	1200308.020	327.31
FM12	161915.112	1200172.343	323.62
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FM24	161706.987	1199787.599	320.91
FM25	161825.139	1199907.237	318.79

LEGEND

- EDGE OF GRAVEL
- BOTTOM OF DITCH
- CHAIN LINK FENCE
- EDGE OF RIP-RAP
- MAJOR CONTOUR
- MINOR CONTOUR
- EDGE OF VEGETATION
- SURVEY CONTROL MONUMENT
- LANDFILL MONITORING MONUMENT

SCALE:
HORZ: 1"=50'
0 50' 100' 150'

N
WASHINGTON STATE PLANE COORDINATE SYSTEM NORTH ZONE - NAD83(1991) 2011(EPOCH 2010.0)

SURVEYED: MC
DESIGNED:
DRAWN: LRL
CHECKED: KWS
CRP No.
DATE: 01/28/2020

KENNETH W. SWINDAMAN
STATE OF WASHINGTON
34430
REGISTERED
PROFESSIONAL LAND SURVEYOR
01/28/2020

KITSAP COUNTY
DEPT. OF PUBLIC WORKS
614 DIVISION STREET MS-26
PORT ORCHARD, WA 98366
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POST-CLOSURE SURVEY
OLALLA LANDFILL

SHEET 1 OF 2 SHEETS

SECTION 1, TOWNSHIP 22, NORTH, RANGE 1 EAST, W.M.
KITSAP COUNTY, WASHINGTON

CHAIN LINK FENCE WITH GAS VENT IN CENTER (TYP.)

Survey Notes:

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LEGEND

EDGE OF GRAVEL
BOTTOM OF DITCH
CHAIN LINK FENCE
EDGE OF RIP-RAP
MAJOR CONTOUR
MINOR CONTOUR
EDGE OF VEGETATION
SURVEY CONTROL MONUMENT
LANDFILL MONITORING MONUMENT

N
WASHINGTON STATE PLANE COORDINATE SYSTEM
NORTH ZONE - NAD83(1991) 2011(EPOCH 2010.0)

SCALE:
HORZ: 1"=50'
0 50' 100' 150'

SURVEYED:	MC
DESIGNED:	
DRAWN:	LRL
CHECKED:	KWS
CRP No.	
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KENNETH W. SWINDAMAN
STATE OF WASHINGTON
34130
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PROFESSIONAL LAND SURVEYOR
01/28/2020

KITSAP COUNTY
18 57
WASHINGTON
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614 DIVISION STREET MS-26
PORT ORCHARD, WA 98366
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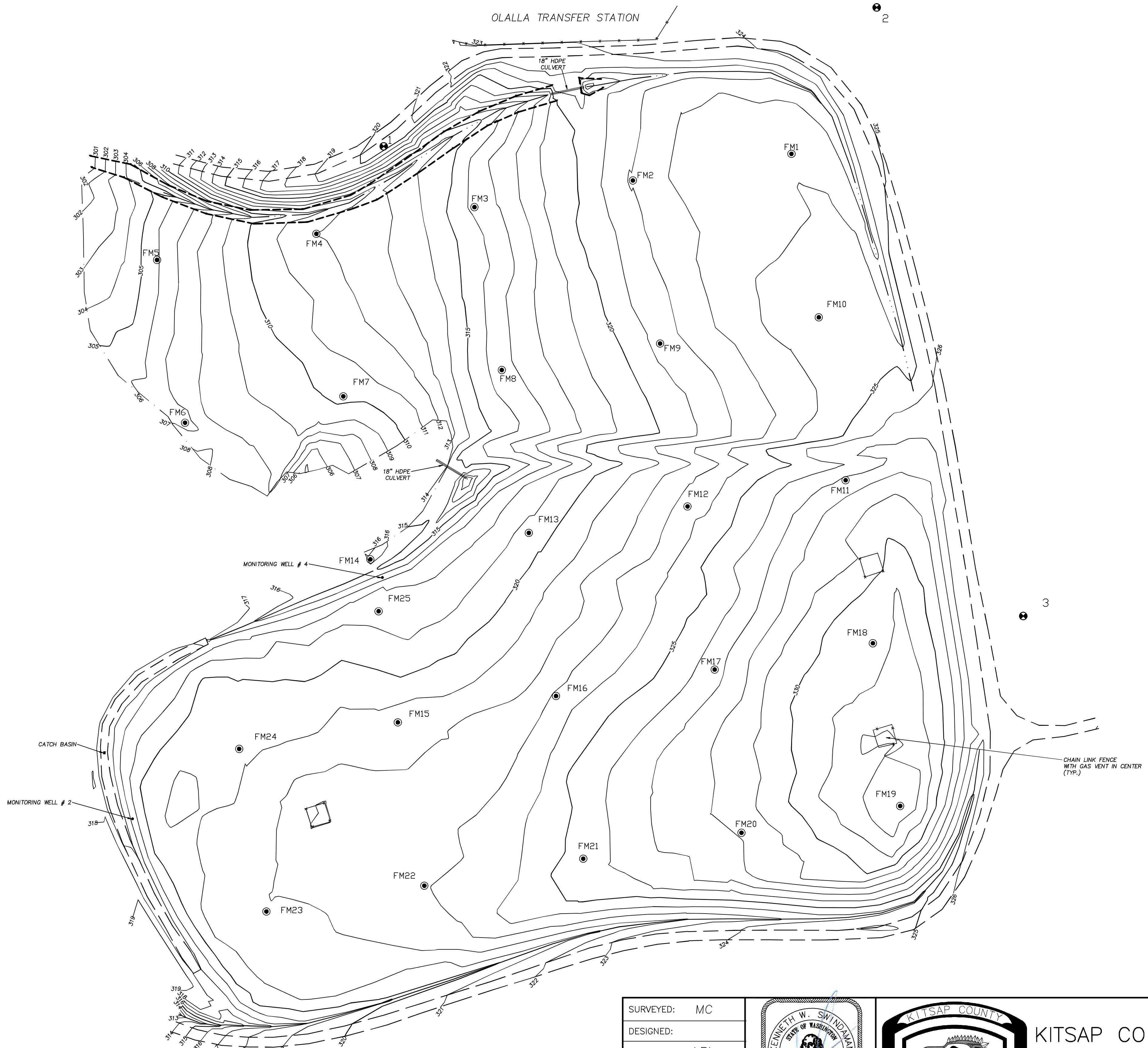
OLALLA LANDFILL
TOPOGRAPHIC MAP

SECTION 1, TOWNSHIP 22, NORTH, RANGE 1 EAST, W.M.
KITSAP COUNTY, WASHINGTON



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LEGEND

- EDGE OF GRAVEL
- BOTTOM OF DITCH
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- LANDFILL MONITORING MONUMENT

N

WASHINGTON STATE PLANE COORDINATE SYSTEM NORTH ZONE - NAD83(1991) 2011(EPOCH 2010.0)

SCALE:
HORZ: 1"=50'
0 50' 100' 150'

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KITSAP COUNTY
WASHINGTON
18 57

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POST-CLOSURE SURVEY
OLALLA LANDFILL

SECTION 1, TOWNSHIP 22, NORTH, RANGE 1 EAST, W.M.
KITSAP COUNTY, WASHINGTON

Survey Notes:

Base map prepared by Kitsap County Public Works Survey Department August 2019, from field survey data gathered July 2019.

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LEGEND

EDGE OF GRAVEL
BOTTOM OF DITCH
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WASHINGTON STATE PLANE COORDINATE SYSTEM NORTH ZONE - NAD83(1991) 2011(EPOCH 2010.0)

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SURVEYED: MC
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KENNETH W. SWINDAMAN
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01/28/2020

KITSAP COUNTY 1857 WASHINGTON

KITSAP COUNTY
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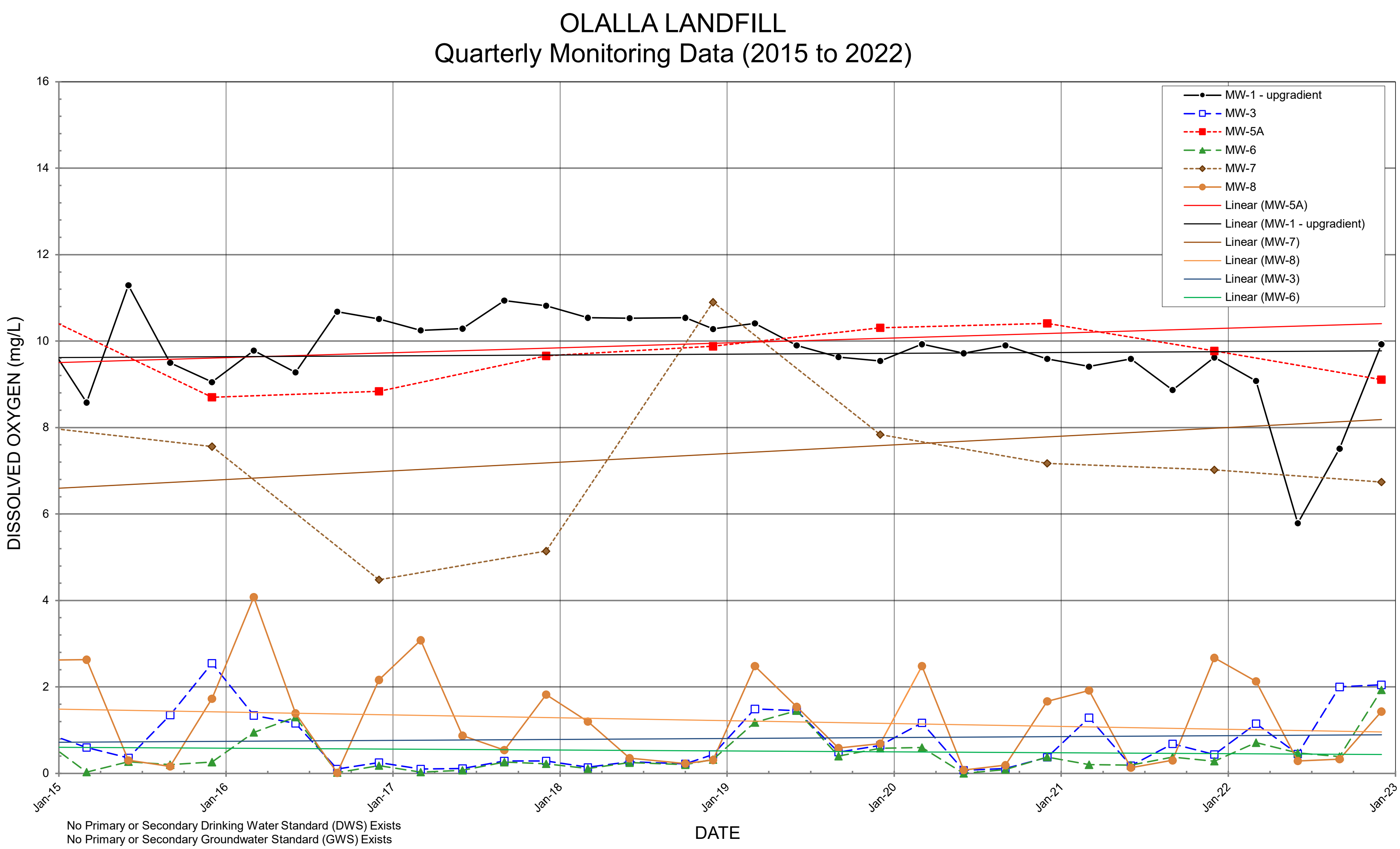
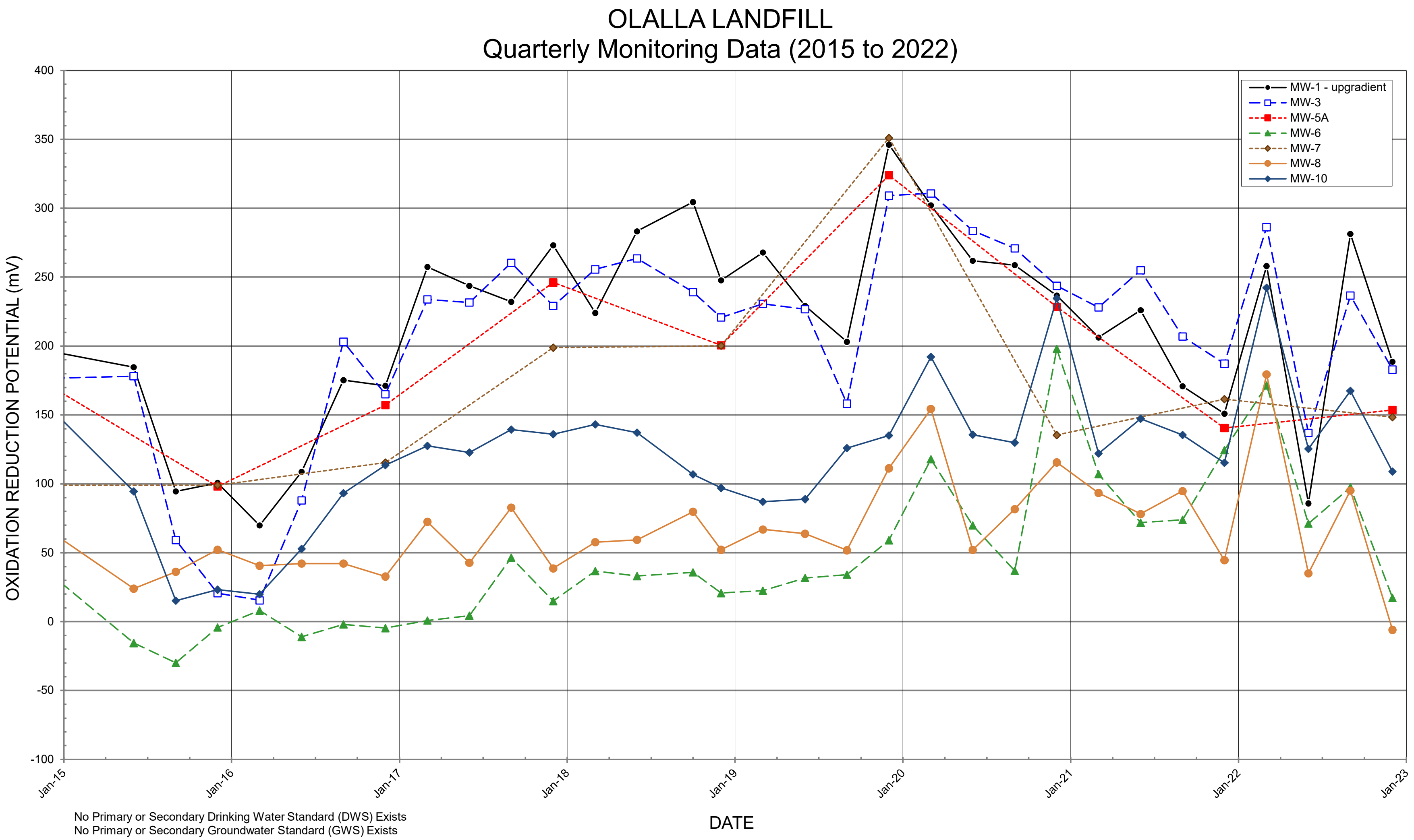
OLALLA LANDFILL TOPOGRAPHIC MAP

SHEET 2 OF 2 SHEETS

Attachment F
Time-Series Plots for Olalla Landfill Geochemical Indicators


OLALLA LANDFILL
Quarterly Monitoring Data (2015 to 2022)
DISSOLVED OXYGEN (mg/L)
16
14
12
10
8
6
4
2
0
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
Jan-21
Jan-22
Jan-23
DATE
MW-1 - upgradient
MW-3
MW-5A
MW-6
MW-7
MW-8
Linear (MW-5A)
Linear (MW-1 - upgradient)
Linear (MW-7)
Linear (MW-8)
Linear (MW-3)
Linear (MW-6)
No Primary or Secondary Drinking Water Standard (DWS) Exists
No Primary or Secondary Groundwater Standard (GWS) Exists



No Primary or Secondary Drinking Water Standard (DWS) Exists
No Primary or Secondary Groundwater Standard (GWS) Exists

Attachment G
New Off-site Well Logs

FILE: ORIG. & FIRST COPY - DEPT. OF ECOLOGY
SECOND COPY - OWNER; THIRD COPY - DRILLER

WATER WELL REPORT

STATE OF WASHINGTON

START CARD NO. WE34202
UNIQUE WELL ID BLH648
WATER RIGHT PERMIT NO

(1) OWNER NAME: HARBOR PUMP — ADDRESS:

(2) LOCATION OF WELL: County KITSAP — NE 1/4 NW 1/4 SEC 1 TWP 22N R 1E

(2a) STREET ADDRESS OF WELL (or nearest address): OLYMPIC DR SE PARCEL # 01220120322006

(3) PROPOSED USE: DOMESTIC
(4) TYPE OF WORK: NEW WELL
METHOD: ROTARY

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 260 feet. Depth of completed well 258 ft.

(6) CONSTRUCTION DETAILS
Casing instld: 6 " Diam. From +1 ft. to 252' 10" ft.
Welded ☑ " Diam. From ft. to ft.
Liner ☐ " Diam. From ft. to ft.
Threaded ☐

Perforations: Yes ☐ No ☑
Type of perforator used
Size of perforations in. by in.
perforations from ft. to in.
perforations from ft. to in.
perforations from ft. to in.

Screens: Yes ☑ No ☐
Manufacturer's Name: JOHNSON
Type STAINLESS Model No.
Diam 5" TEL Slot size 0.010 from 252' ft. to 257' 11" ft.
Diam Slot size from ft. to ft.

Gravel packed Yes ☐ No ☑ Size of gravel?
Gravel packed from ft. to ft.

Surface seal: Yes ☑ No ☐ To what depth? 18 ft.
Material used in seal BENTONITE CHIPS
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? Depth of Strata ft.
Method of sealling strata off

(7) PUMP: Manufacturer's Name
Type H. P.

(8) WATER LEVELS: Surface elev above mean sea level ft.
Static level 85 below top of well Date 03/14/19
Artesian pressure lbs. Per sq. in. Date
Artesian pressure is controlled by

(9) WELL TESTS: Pump test made? By Whom
Yield gal./min with ft. drawdown after hrs.
Yield gal./min with ft. drawdown after hrs.
Yield gal./min with ft. drawdown after hrs.
Recovery data:
Time Wtr Lvl. Time Wtr Lvl. Time Wtr Lvl.

Date of test:
Bailer test gal./min with ft. drawdown after hrs.
Airtest 20 gal/min stem set at 250 ft. for 1 hrs.
Artesion flow gal/min Date
Temperature of water Was chemical analysis made? NO

(10) WELL LOG OR DECOMMISSIONING PROCEDURE DESCRIPTION

MATERIAL	FROM	TO
DARK BROWN CLAYEY SLIT, SOME FINE SAND	0	4
LT BROWN SILT & FINE SAND	4	49
GRAY SILT & FINE SAND	49	95
GRAY SILTY CLAY	95	185
GRAY SILT & SOME FINE SAND	185	188
GRAY SILTY CLAY	188	229
GRAY SILT & VERY FINE SAND (W.B.)	229	250
GRAY SILT & FINE TO COARSE SAND, TRACE GRAVEL (W.B.)	250	253
GRAY SILT & FINE TO COARSE SAND & TRACE GRAVEL (W.B.)	253	258
BROWN SILT & GRAY VERY FINE SAND (W.B.)	258	260
SCREEN ASSEMBLY - 5" 2' 8" W/"K" PACKER, 5' .010 6T STAINLESS STEEL SCREEN W/PLATE BOTTOM 7' 11" TOTAL LENGTH		

RECEIVED
DEPT OF ECOLOGY
MAR 29 2019
WATER RESOURCES PROGRAM
NORTHWEST REGIONAL OFFICE

Work Started 03/07/19 Completed: 03/14/19

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

Name: RICHARDSON WELL DRILLING COMPANY INC.
Address: P. O. BOX 44427 TACOMA, WA 98444
(Signed) [signature] (Well Driller) Lic No. 2081
Contractor's Registration No. RICHAW*3210B DATE 3/20/19

FILE: ORIG. & FIRST COPY - DEPT. OF ECOLOGY
SECOND COPY - OWNER; THIRD COPY - DRILLER

WATER WELL REPORT

STATE OF WASHINGTON

START CARD NO. WE34934
UNIQUE WELL ID BME039
WATER RIGHT PERMIT NO

(1) OWNER NAME: **HARBOR PUMP/OLYMPIC DR** ADDRESS: **PO BOX 330 BURLEY, WA 98332**
(2) LOCATION OF WELL: County **KITSAP** **NE** 1/4 **NE** 1/4 SEC **1** TWP **22N** R **1E**
(2a) STREET ADDRESS OF WELL (or nearest address): **XXX OLYMPIC DR SE PARCEL #01220120312007**

(3) PROPOSED USE: **DOMESTIC**
(4) TYPE OF WORK: **NEW WELL**
METHOD: **ROTARY**

(5) DIMENSIONS: Diameter of well **6** inches.
Drilled **257** feet. Depth of completed well **256** ft.

(6) CONSTRUCTION DETAILS
Casing instld: **6** " Diam. From ft. to **246.5** ft.
Welded ☑ " Diam. From ft. to ft.
Liner ☐ " Diam. From ft. to ft.
Threaded ☐

Perforations: Yes ☐ No ☑
Type of perforator used
Size of perforations in. by in.
perforations from 5 ft. to in.
perforations from ft. to in.
perforations from ft. to in.

Screens: Yes ☑ No ☐
Manufacturer's Name:
Type Model No.
Diam 6" TEL Slot size 16 from 250.7 ft. to 256.0 ft.
Diam Slot size from ft. to ft.

Gravel packed Yes ☐ No ☑ Size of gravel?
Gravel packed from ft. to ft.

Surface seal: Yes ☑ No ☐ To what depth? **18** ft.
Material used in seal **BENTONITE CHIPS**
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? Depth of Strata ft.
Method of sealling strata off

(7) PUMP: Manufacturer's Name
Type H. P.

(8) WATER LEVELS: Surface elev above mean sea level ft.
Static level **95** below top of well Date **04/29/19**
Artesian pressure lbs. Per sq. in. Date
Artesian pressure is controlled by

(9) WELL TESTS: Pump test made? By Whom
Yield gal./min with ft. drawdown after hrs.
Yield gal./min with ft. drawdown after hrs.
Yield gal./min with ft. drawdown after hrs.
Recovery data:
Time Wtr Lvl. Time Wtr Lvl. Time Wtr Lvl.

Date of test:
Bailer test gal./min with ft. drawdown after hrs.
Airtest **100** gal/min stem set at **255** ft. for **1** hrs.
Artesion flow gal/min Date
Temperature of water Was chemical analysis made? **NO**

(10) WELL LOG OR DECOMMISSIONING PROCEDURE DESCRIPTION

MATERIAL	FROM	TO
LIGHT GRAYISH BROWN SILTY SAND GRAVEL	0	15
GRAYISH BORWIN TRACE GRAVEL SILTY SAND	15	49
GRAY FINE SILTY SAND SOME WATER	49	88
GRAY FINE SAND SOFT CLAY	88	128
GRAY SAND SOME WATER	128	131
GRAY CLAY	131	246
Grey Small gravelly Silty Sand, water	246	257

TOP OF PACKER 248.7

Work Started 04/25/19 Completed: 04/29/19

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

Name: **RICHARDSON WELL DRILLING COMPANY INC.**
Address: **P. O. BOX 44427 TACOMA, WA 98444**
(Signed) [signature] Lic No. **2432**
(Well Driller)
Contractor's Registration No. **RICHAW*3210B** DATE **5/1/19**

.E: ORIG. & FIRST COPY - DEPT. OF ECOLOGY
SECOND COPY - OWNER; THIRD COPY - DRILLER

WATER WELL REPORT
STATE OF WASHINGTON

START CARD NO. WE17915
UNIQUE WELL ID BIJ937
WATER RIGHT PERMIT NO N/A

(1) OWNER NAME: **LEO PIERSON** ADDRESS: **3340 HIDDEN VALLEY WAY OLALLA WA. 98359**
(2) LOCATION OF WELL: County **KITSAP** **NW** 1/4 **NE** 1/4 SEC **1** TWP **22N** R **01E**
2a) STREET ADDRESS OF WELL (or nearest address): **2420 BURLEY OLALLA RD** **PARCEL 01220110312009**

(3) PROPOSED USE: **DOMESTIC**
(4) TYPE OF WORK: **NEW WELL**
METHOD: **ROTARY**

(5) DIMENSIONS: Diameter of well **6** inches.
Drilled **295** feet. Depth of completed well **293' 5"** ft.

(6) CONSTRUCTION DETAILS
Casing instld: **6** " Diam. From ft. to **288' 9"** ft.
Welded ☑ " Diam. From ft. to ft.
Liner ☐ " Diam. From ft. to ft.
Threaded ☐

Perforations: Yes ☐ No ☑
Type of perforator used
Size of perforations in. by in.
perforations from ft. to in.
perforations from ft. to in.
perforations from ft. to in.

Screens: Yes ☑ No ☐
Manufacturer's Name: **JOHNSON**
Type **STAINLESS** Model No.
Diam **6" TEL** Slot size **18** from **288'** ft. to **293' 5"** ft.
Diam Slot size from ft. to ft.

Gravel packed Yes ☐ No ☑ Size of gravel?
Gravel packed from ft. to ft.

Surface seal: Yes ☑ No ☐ To what depth? **18** ft.
Material used in seal **BENTONITE CHIPS**
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? Depth of Strata ft.
Method of sealling strata off

(7) PUMP: Manufacturer's Name
Type H. P.

(8) WATER LEVELS: Surface elev above mean sea level ft.
Static level **99** below top of well Date **04/08/14**
Artesian pressure lbs. Per sq. in. Date
Artesian pressure is controlled by

(9) WELL TESTS: Pump test made? By Whom
Yield gal./min with ft. drawdown after hrs.
Yield gal./min with ft. drawdown after hrs.
Yield gal./min with ft. drawdown after hrs.
Recovery data:
ne Wtr Lvl. Time Wtr Lvl. Time Wtr Lvl.

Date of test:
iler test gal./min with ft. drawdown after hrs.
test **100+** gal/min stem set at **290** ft. for **1** hrs.
esion flow gal/min Date
mperature of water Was chemical analysis made? **NO**

(10) WELL LOG OR DECOMMISSIONING PROCEDURE DESCRIPTION

MATERIAL	FROM	TO
TOPSOIL	0	1
BROWN SILTY SAND	1	5
BROWN SILTY SAND, GRAVEL	5	12
BROWN SILTY SAND	12	25
BROWN CLAY	25	35
BROWN SILTY SAND	35	64
GREY SILTY SAND	64	66
BROWN FINE SAND,	66	103
GREY CLAY	103	132
GREY FINE SAND,	132	147
GREY CLAY	147	262
GREY FINE SAND, WATER	262	280
GREY SAND, WATER	280	290
GREY SAND, GRAVEL, WATER	290	295
AIR TESTED 60 GPM WITH STEM SET AT 200' FOR 1/2 HR		

RECEIVED
JUN 03 2014
DEPT OF ECOLOGY
NWRO - WQ

Work Started 04/03/14 Completed: 04/08/14

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

Name: **RICHARDSON WELL DRILLING COMPANY INC.**
Address: **P. O. BOX 44427 TACOMA, WA 98444**
(Signed) _______ (Well Driller) Lic No. **2246**
Contractor's Registration No. **RICHAW*3210B** DATE **4/9/14**